# SUSTAINABLE BUILDINGS AND RENEWABLE ENERGY

A CASE STUDY OF A PUBLIC LEISURE CENTER DESIGN


Mina Abbasi Toughchi


Final Project of Master

**Supervisor**

Professor Doctor António Leite

**Supervisor**

Professor Doctor Jorge Ribeiro

Lisbon, FAUL, March of 2017

# Table of Contents

# Table of Figures

# List of Tables

# Abstract

Nowadays climate change and the greenhouse effect are important global issues which need the cooperation between different fields of study to be solved. The solution is bilateral, on one side there is a significant effort in the European Union to replace conventional energy resources with renewable energy such as Solar, Wind, Wave and Tidal while another solution is to optimize the consumptions.

Sustainable buildings and zero-energy buildings are the main solutions in efficient building designs. In case of sustainability in building and architectural industry, Zero Energy Building is a state of the art technology which takes the advantage of local renewable energy resources while it is built optimally with natural heating, cooling, and lighting to consume water and energy in lowest possible level. On the other hand, European road map in different fields of urban development, smart city and green cities, needs a considerable attention in sustainable and zero energy buildings.

In this project, a sustainable building is designed to operate as a public leisure center in the old and touristic region of Lisbon. One of the main issues in sustainable construction in historical spots is the morphology of the region and the geographic situations that can not be changed because of the negative impact that it will have in the apearance of the region. So, In this thesis a vacant lot of the city is used as the project land and the design is fulfilled based on the zone charectristics, potentials and constraints. The functionality of the building includes a health club, two shops, and a restaurant in addition to a green space. Also, a stairway passing through the green space increases the accessability of the region which is one of the key problems in that area of Lisbon.

**Keywords:** Climate change, Renewable energy, Sustainable building, Zero-energy building, Historical region, Vacant lot.

# 1 INTRODUCTION

We are living in a planet which suffers many climate problems such as global warming, air pollution and water scarcity. One of the main issues in almost all the capitals of Europe is to optimize their energy and water consumption in both habitations and industries. Expectedly, the biggest challenge in future smart house projects is resource management in term of water and energy. So, in this case, the weight of sustainable and efficient building design is bigger than robotics or autonomous home facility development. Also, all the cutting edge technologies in different fields of renewable energy and energy-saving have to find their ways into cities to meet the needs for sustainable zero energy building design. Lisbon is now one of the leaders in European smart city projects while a significant part of the city is covered with old and un-efficient buildings (Sharing Cities Programme, 2016).

A net zero-energy building (ZEB) is a private or commercial building with considerably decreased energy needs by efficiency gains such that the balance of energy requirements can be provided with renewable technologies. On the other hand, a ZEB creates enough renewable energy to meet its annual power consumption demands, through decreasing the use of non-renewable energy in the building sector. ZEBs use all cost-effective measures to reduce energy usage through energy effciency and include renewable energy systems that produce enough energy to meet remaining energy needs.

There are many long-term benefits of leading toward ZEBs, including lower environmental impacts, lower operating and maintenance costs, better resiliency to power outages and natural disasters, and enhanced energy security.

Portugal is one of the well-known renewable energy based countries in Europe which in 2016 met 100% its energy consumption from renewable resources such as solar, wind, and offshore. While, this does not mean that homes and industries are connected to renewable energy grid, but at least Portugal is the first country in the world which claims enough resources in the renewable sites (Guardian, 2016).

Before launching renewable energy for habitations and industries, municipalities have to prepare the infrastructures in term of ZEB projects. One of the main challenges in ZEB projects is the historical and old fashion areas in cities where architectures cannot define projects for building new structures or change the style of the town at all. For example, ZEB concept will face series of challenges in Lisbon especially in areas such as Martim Moniz, Rossio, Baixa-Chiado, etc.

## 1.1 Objectives

The main goal in this project is to define the challenges in a vacant lot in Martim Moniz area as a case study for incorporation of sustainability. Then a solution will be proposed for this area and the final dissemination of this project would be a model for a sustainable building which covers all the definitions in ZEB concept. Other objectives of this project are:

- To study different renewable energy resources and utilization process.
- To comprehend the importance of future ZEBs compared to conventional buildings that we have in big cities such as Lisbon.
- Understand and define the architectural elements of the building which affect the energy usage of the building.

- Find the challenges in the historical part of Lisbon city for becoming green and sustainable.
- Assess the capability of vacant lots in the region to build or renew buildings incorporating ZEB objectives.

### **1.2** Methodology

In this thesis both practical and theoretical methodologies are applied to find the most suitable solution for the project. Followings are the highlighted methods of research that are applied in this thesis:

- Literature review: the base of this study will be empowered by related books, papers and European road maps in ZEB and sustainable building fields. Also based on defined keywords the novelty in a variety of papers will be considered in this project.
- Analysis of data collected from reviewing papers, books and other references. Firstly, the main elements in the literature review will be investigated, and the related concepts will be studied intensely in term of methods, materials, and strategies.
- Selection and analysis of a case study illustrating detail as a strategy to approach the project. In this section of methodology, we compile the challenges and problems in the case study region and try to validate the problem before proposing any solutions.
- Measurement, survey and elaboration of technical drawings that constitute a reliable basis for the development of the project. These elements are complemented by photographic and physical studies, which may represent suitable bases for the creation of sustainable design solutions.
- Study the solutions of the project. The solutions will come up with understanding the situations in the case study and investigating literature review. Meanwhile, comprehending the selected region as a case study will help us to add more values to our solutions. Then the ZEB will appear as a solution for building a new structure or renewing an existing one.
- Elaborating the final elements of the project: technical drawings, 3D digital/virtual models (CADs) and scaled prototypes, that provides a clear and understandable project.
- Evaluation of the final results, reflecting if and how the defined objectives are achieved.

### **1.3** Document structure

In this document, the renewable energy resources and their utilization processes are described in section 2. Also, environmental impact of the construction is studied and different sustainable techniques and materials are presented. In section 3, Martim Moniz region and its characteristics as a case study of this project is studied. The case study land of this project is an unused space near the Martim Moniz area. Then the area constraints for a sustainable building project are explored. Finally, in section 4 the site analysis process including the conceptual design of the project are presented and the schematic and urban project was defined.

# **2** STATE OF THE ART

Nowadays, the global warming, climate change and water scarcity are amongst the main human issues in the world. After centuries of consuming fossil resources in developed countries, they found their populations endangered by health and well-being problems. In order to find a solution, developed and industrial countries are the pioneers of replacing their energy resources with renewable ones (Vörösmarty *et al*., 2000).

In recent years, international climate policy has frequently focused on restricting temperature rise, as argued to achieve greenhouse gas concentration related objectives. The agreements reached at the United Nations Framework Convention on Climate Change conference (United Nations, 2011) recognize that countries should take urgent action to limit the increase in global average temperature to less than 2 °C relative to pre-industrial levels. If this is to be achieved, policymakers need robust information about the quantities of future greenhouse-gas emissions that are consistent with such temperature limits. This, in turn, requires an insight of both the technological and financial indications of reducing emissions and the processes that link emissions to temperature (Rogelj *et al*., 2011).

## **2.1** Energy and resources

### **2.1.1** Fossil fuel

Hydrocarbon-based fuels are also identified as fossil fuels because they are obtained from the centuries-old remains of decayed plants and animals that were captured in geological deposits. These fuels include coal, oil, and natural gas. They are considered nonrenewable energy sources because they take millions of years to form and cannot be easily replaced after use. As fossil fuels became the dominant source of energy, less and less attention was paid to the energy sources of the past: Solar and Wind.

### **2.1.2** Renewable energy and its resources

Renewable energy technologies are those that harness energy from a limitless source. Such sources involve the sun, wind, falling water, waves, tides, biomass, or heat generated under the surface of the Earth. Most renewable energy sources, except geothermal, are obtained from the sun (**Figure 1**). Solar energy comes directly from the thermal energy given off by the sun. Sources like wind, hydropower (hydro), waves, and tides are the result of solar energy. The Wind is created by the differential heating of the Earth's surface by the sun, wind creates waves, and tides are the result of the gravitational influence of the moon and the sun on the Earth. Biomass is actually chemical energy stored in plants that was converted from solar energy through the process of photosynthesis. Renewable energy technologies include solar, wind, hydro, geothermal, biomass, and ocean, which includes tidal and wave power (Johansson, 1993; Tester *et al.*, 2012).

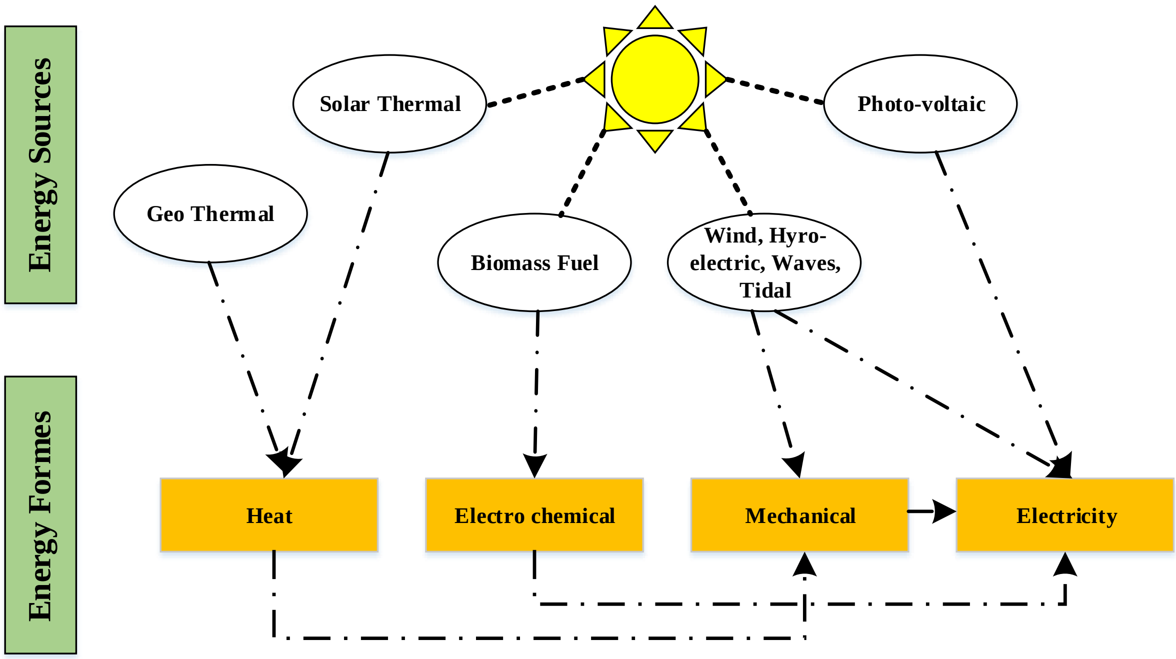



***Figure 1 Energy sources and conversions*** **(adapted from Tester *et al*., 2012)**

Renewable energy can be employed in different urban areas including residential and commercial buildings, and transportation systems. In Portugal renewable energy was the source for 25.8% of energy consumption in 2014, namely from biomass, hydropower, wind power, biofuels, solar power, biogas, urban solid waste and geothermal (DGEG/PORDATA, 2017a). In 2015, 48.6% of Portugal's electricity requirements were supplied by renewable sources, namely from biomass, hydropower, wind power, geothermal power, solar power (DGEG/PORDATA, 2017b).

*2.1.2.1 Solar energy resources*

Solar energy is solely the capture of heat energy from sunlight. Solar energy has been used domestically for heating and cooking since the dawn of human civilization. Ancient societies used methods of passive solar capture to heat dwellings. The first modern solar technology can be traced back to the late 1700s when Antoine Lavoisier produced the first solar furnace (Smith & Taylor, 2008). Solar was applied in the 1880s in India for cooking (Patel, 2013). Simple steam engines have been powered by solar since 1878 (Kongtragool & Wongwises, 2003)). In 1913, Egypt developed a solar-powered water pump for irrigation (Delgado-Torres, 2009). Solar hot water heaters have been popular in the United States since the 1930s (Cleveland *et al.*, 1984). The first photovoltaic (PV) cells, used to produce electricity, were developed in the late 1950s and were used to provide electrical power for satellites orbiting the Earth (Shah, *et al.*, 1999). Improvements to PV technologies in the 1970s helped to reduce their costs and allowed for their use in more applications, all of which met low-power needs. After the energy crisis in of the 1970s, PV power systems with utility grid–connected applications emerged worldwide, and solar energy began to be seen as a viable energy origin.

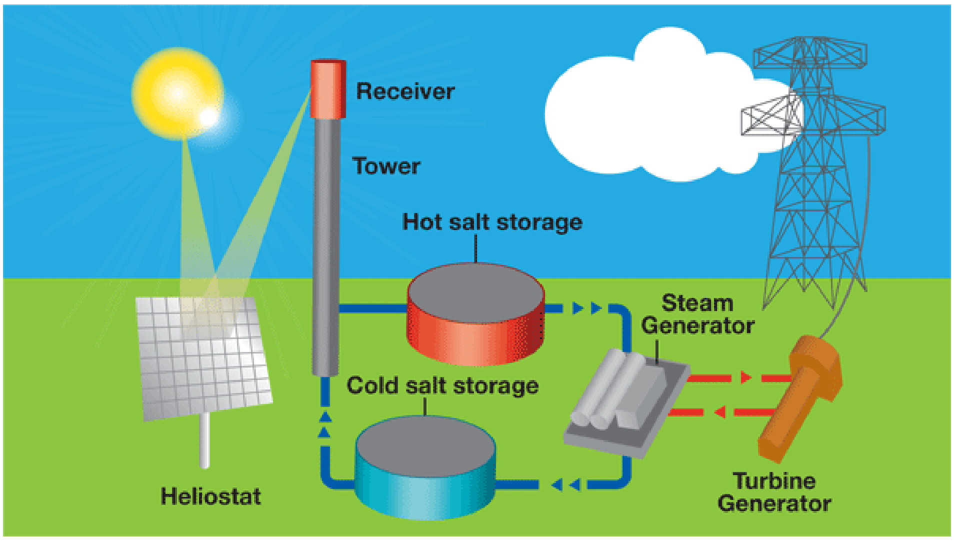



*Figure 2 Solar energy resources and utilization* **(adapted from clipart solar power library, 2017)**

Solar power is utilized by one of three methods. The first is solar thermic systems in buildings, which capture solar energy in two ways: actively or passively. For passive solar heating, buildings are designed in a way that captures heat and transmits daylight. This method requires the suitable orientation of the building facade and strategic placement of windows in the construction design so that the maximum solar energy potential is captured. Active solar heating is essentially the capture of solar energy using solar panel collectors in which the thermal energy is usually transmitted through a liquid medium. This type of solar energy is generally used for hot water heaters and for space heating and cooling.

The second method of utilization is through photovoltaic (PV) panels. The PV panels are solid-state semiconductor devices that convert sunlight directly into electricity, which can then be used for several types of applications. PV panels require no moving parts or fluids, and they are made of one of three types of silicon or come in the form of a thin film made from other semiconductor materials. PV systems can be stand-alone, roof mounted, or developed as roof shingles. In Europe, the Germany is a leader in the installed photovoltaic power, even though it is not one of the countries with the highest photovoltaic potential, since the solar incidence conditions are not the best when compared, for example, with Portugal or Spain. In second place is Italy, followed by Spain and France, with significant values of installed power (Pereira, 2015). Although Portugal already had an installed capacity of around 400MW (DGEG, 2014), the objectives set for 2020 under the NREAP (National Renewable Energy Action Plan), Portugal will have to install around 60MW per year (Pereira, 2015).

The third method of utilization is a technology called a central solar power (CSP) system, also known as a concentrating system (**Figure 2**). Sunlight is focused or concentrated to generate steam, which is then used to run turbo generators. There are three types of CSP systems:

a) Parabolic trough systems use concentrators that focus sunlight into a tube that runs the length of the trough;
b) Towers collect sunlight using fields of sun-tracking mirrors known as heliostats and concentrate the heat onto a centrally located tower-mounted receiver where it heats a liquid, which is constantly circulated;

c) Parabolic dishes, or dish-engine systems, concentrate sunlight onto a focal point in the middle of a dish, where the heat is then transferred to an engine and converted to mechanical energy.

Base on the investigation done in this literature (Zondag, et al., 2006), amongst all of the European countries the highest potential for solar power generation is in Portugal, and in the Mediterranean region with strong peaks in cloudless summer (Malta, Cyprus, most parts of Spain, Italy and Croatia, Southern France and Corsica, Greece and Southern Turkey). In this region in the urban residential areas, a typical crystalline silicon PV system generates annual electricity between 1100 and 1330 kWh per installed kWp.

*2.1.2.2 Wind resources*

The Wind is the result of the differential heating of the Earth's surface (Archer & Jacobson, 2005; Smith & Taylor, 2008). Differential heat is the variation between how much heat is received by land and how much is absorbed by water surfaces. Wind energy is captured via a turbine, which turns as the wind blows. The turbine produces mechanical or electrical energy, which can then be applied for a variety of purposes (**Figure 3**). The earliest documentation of windmills can be found in the writings of an Islamist geographer who recorded the use of vertical-axis windmills in Persia in 9th century. Windmills have been used in Europe since the 12th century, and their use has been documented in China since the 13th century. The first commercial wind turbine that produced electricity was built in Vermont in 1939 (Johnson, 1985). Currently, the primary use for wind power is electricity generation.

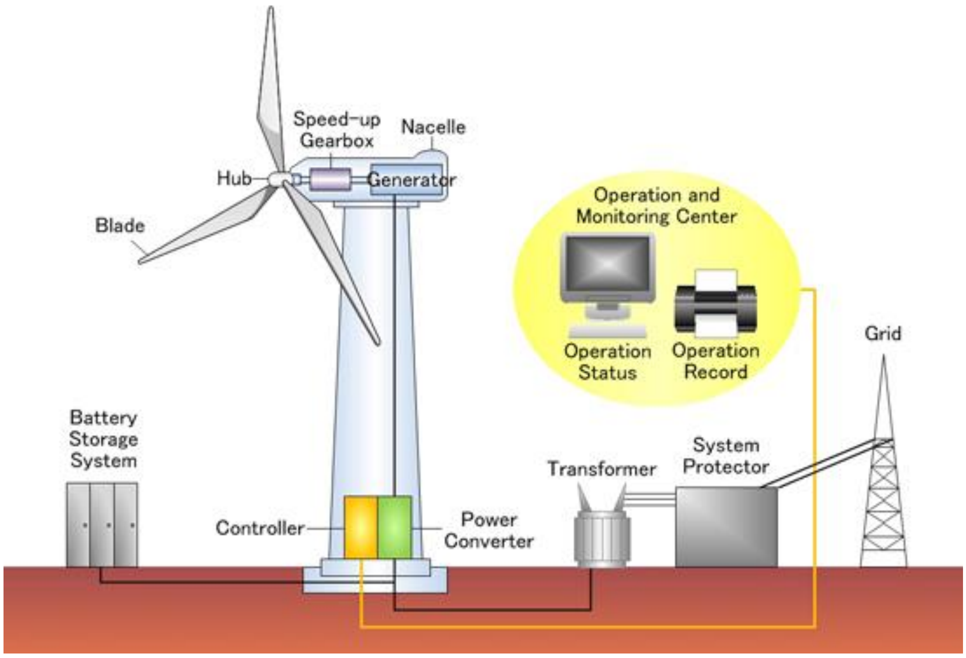



***Figure 3 Wind resource and utilization*** **(adapted from Johnson, 1985)**

Unlike solar power, wind power is captured with typically only one type of technology: turbines. Large-scale turbines are made up of two rotors consisting of two or three propeller-like blades attached to a nacelle (the housing containing the electric generator, gear box, and brake), which is held up by a support tower. Small-scale turbines are similar to the large-scale types, but the rotor powers the electric generator directly without a gear box, and they tend to be only 7.5m to 10m high. Horizontal-axis wind turbines (HAWT) are much more common than vertical axis wind turbines (VAWT). HAWTs are similar to propellers, whereas VAWTs look exactly like eggbeaters. Also, VAWTs tend not to be as efficient as HAWT units, which is why all grid-connected commercial wind turbines are horizontal (Bianchi, et al., 2007). Wind turbines are usually grouped together within the same area of land. These groupings, called wind farms, generate bulk electric power to be fed into the grid like traditional forms of energy.

If wind energy technology continues at its current rate of adoption, it will likely meet 10 to 20% of the world's electrical needs by 2050. Worldwide offshore wind potential is large enough to provide for the current electricity needs of the entire planet. Recent studies show that, if even 20% of implied wind energy sites were exploited, they could generate enough power for the world's needs (Blanco, 2009). Nowadays, wind energy is producing 15% of all demanded energies in Europe (Lantz et al, 2012). Meanwhile, renewable energy companies in France and Scotland are offering technologies with 8MW annual energy production per unit of wind turbine.

#### *2.1.2.3 Hydroelectric resources*

Hydropower is energy captured from falling or running water, usually rivers (Locher & Scanlon, 2012). Hydropower technology can be developed on a large or small scale. Large-scale hydro generally refers to massive dams. The precise categorization is contingent on the amount of electricity produced by a hydropower project. Small-scale hydro captures energy through the use of smaller dams and river turbines. It is usually considered small scale if it produces less than 50 MWs of electricity, but the definition varies by country. Historically, hydropower has been used to run mills and to generate mechanical energy for industrial applications. It was first used to produce electricity in 1881 in Surrey, England (Okot, 2013). Currently, there are over 45,000 large dams in over 140 countries, although not all of them generate electricity. Alternative uses for dams include the storage of water in reservoirs for watering and other water needs, as well as water oriented entertainment.

The most widely adopted process of employing hydropower is through large-scale hydro projects that involve the construction of an impoundment dam on a river. The dam holds water in a reservoir and leads the flow of water into a penstock, which carries it to the turbines installed in the dam. The turbines are connected to electric generators, and, as the water spins the turbines, the generators create electricity. When power does not need to be generated, water is kept in the reservoir for future use. Small-scale projects are generally referred to as micro-hydropower. They include projects known as "run of the river" that use the natural flow of the water to spin turbines or waterwheels (**Figure 4**).

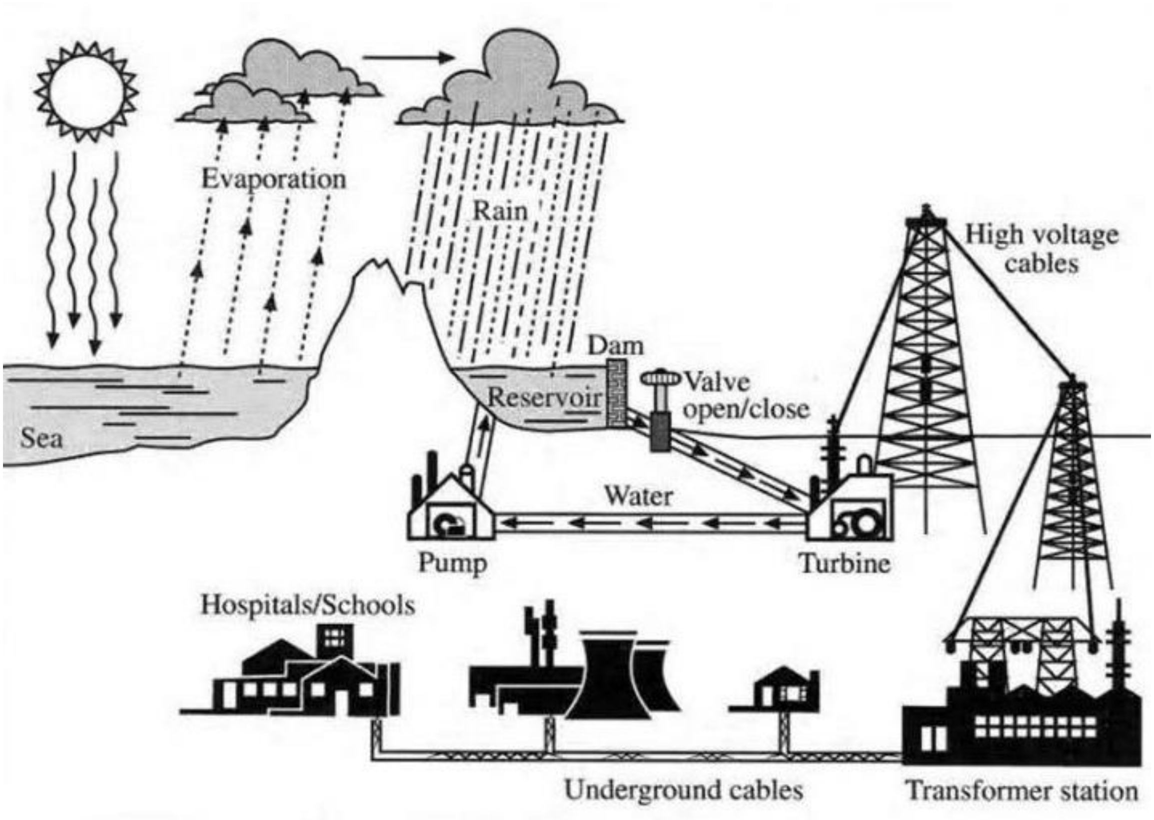



***Figure 4 Hydro-electric resources and utilization*** **(adapted from Brookshier, 2004)**

The advantages for hydropower are distinct for large and small-scale projects. Large-scale projects have low operating costs and longer supposed power plant life than any other form of electricity production. This fact makes for very low consumer prices. Reservoirs often serve multiple purposes, including providing a source for irrigation, drinking water, recreation, flood protection, and resources for aquaculture. Small-scale hydropower is particularly useful for low energy–intensity uses like those of developing countries. It is more economically feasible for countries that do not have the capital to invest in large-scale hydropower. It is also beneficial for remote areas where the transmission of electricity is involved. They have all of the benefits of large-scale hydro, except for those related to the reservoirs themselves like recreation, and hardly any of the disadvantages. Therefore, they have minimal environmental impacts compared to large-scale projects and fossil fuel usage.

Hydroelectricity is electricity produced from hydropower. In 2015 hydropower generated 16.6% of the world's total electricity and 70% of all renewable electricity, and was expected to increase about 3.1% each year for the next 25 years (Okot, 2013). In Portugal, hydropower generated an important part (31.1% in 2014 and 18.7% in 2015) of total electricity (DGEG/PORDATA, 2017c).

*2.1.2.4 Geothermal resources*

Geothermal power is the heat that is stored in the Earth's shell, usually beneath the ground (Armstead, 1978). It is created by the breakdown of radioactive minerals underneath the Earth's surface. Hot springs and geysers are examples of geothermal energy that has traveled aboveground through the medium of water or steam (**Figure 5**). This type of geothermal energy source is known collectively as hydrothermal or convection-dominated, referring to the production of hot fluid. This category also includes boiling mud pots and fumaroles (steam or gas vents). Hydrothermal sources are generally found in mountainous areas, near volcanoes, and at the edges of crustal plates. Distribution of these sources is largely related to plate tectonics. Steam-dominated systems are the least common of all the geothermal sources, and they are the primary sources and locations for geothermal power plants because their temperature can get high enough to be converted into electricity (Hurter & Haenel, 2002). Geothermal energy can also be found in hot dry rock. Hot, dry rock is separable from hydrothermal due to the lack of fluid. This is the most common form of geothermal energy systems and also more difficult to extract heat from than hydrothermal systems. Wells must be penetrated into the rock and fluids circulated to transfer heat from underground to where it is demanded above ground. The last type of geothermal system is magma. Magma is the rock that is partially or completely molten. It can usually be found only at great depths, requiring intensive drilling and making extraction the most difficult, although not impossible, of all the geothermal resources (Roche *et al*., 2017).

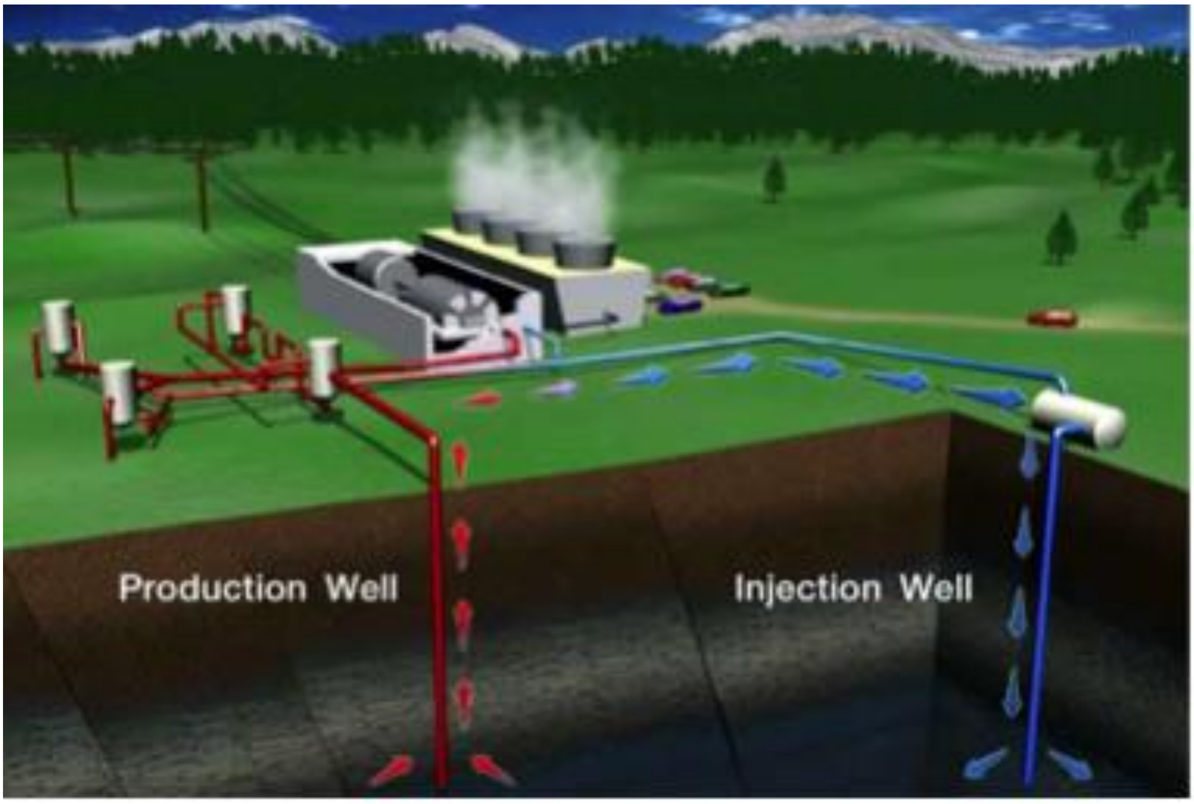



***Figure 5 Geo thermal resources and utilization*** **(adapted from Debatepedia, 2017)**

The earliest usage of geothermal energy probably dates back to prehistoric times when humans likely bathed in hot springs. It was first used for commercial electricity production in the early 1900s in Larderello, Italy, from steam vents and drilled holes in what is known as the Larderello field (Reinsch et al., 2017). Use of geothermal for electricity generation has expanded to the United States, Japan, Mexico, Iceland, and the Philippines, to name a few. Geothermal ranks third in the United States for renewable energy use behind biomass and hydropower.

To utilize geothermal systems, access to the sources of heat must be gained. This generally involves drilling techniques similar to those used by the oil and gas industry. The liquid is essential because it is the medium needed to transport the heat. It must therefore either exist at the source, as in hydrothermal systems or be brought in externally and run through pipes where it can be heated by hot dry rocks or magma and circulated to generate energy. The use of geothermal is very similar to that of solar. It can be incorporated into building structures through the use of pipe systems for heating and cooling when the structures are near the source. It can also be used to generate electricity in large-scale power plants, which must also be located near the source. In Portugal the production of electricity by geothermal source represents less than 1% in 2015 (DGEG/PORDATA, 2017c).

#### *2.1.2.5 Biomass*

Biomass consists of virtually any living plant material as well as organic wastes from sources such as humans and plants. The storage of solar power through photosynthesis creates products with a high-energy content, like carbohydrates, which can be used as an energy source when combusted. The ability to generate large quantities of biomass on a short timescale makes it possible for continued human use of them. Hence, they are considered a renewable energy. biomass takes one of four different forms (Arshadi & Sellstedt, 2008):

- Biogas: Methane is the most usually used biogas and is emitted through the decay of organic waste.
- Solid biofuels: These can be obtained from farming crops, woods, organic waste.
- Liquid biofuels: Biodiesel and ethanol are the most common liquid biofuels and have received a considerable amount of attention in the media over the last decade as the political windows have opened for favorable legislation.
- Energy crops: These are crops grown particularly for use as a solid or liquid biofuel. Corn and sugar cane are the most common crops, grown for the production of ethanol.

Biomass can be converted to energy through a number of processes (**Figure 6**). The principal method of utilization is through thermal conversion, which is the combustion of biomass to create energy or fuel. The process of bioconversion is the direct or indirect use of the chemical composition of living things to transform one substance to another. Fermentation and hydrolysis are used to create ethyl alcohol or ethanol, a high-quality fuel that can be used for transportation or electricity production. Biogas producers, already mentioned and also known as digesters, are contraptions that use anaerobic bacteria to process animal waste and sewage as well as landfill material to create methane, which is then captured and used (Greanandgrowing, 2017).

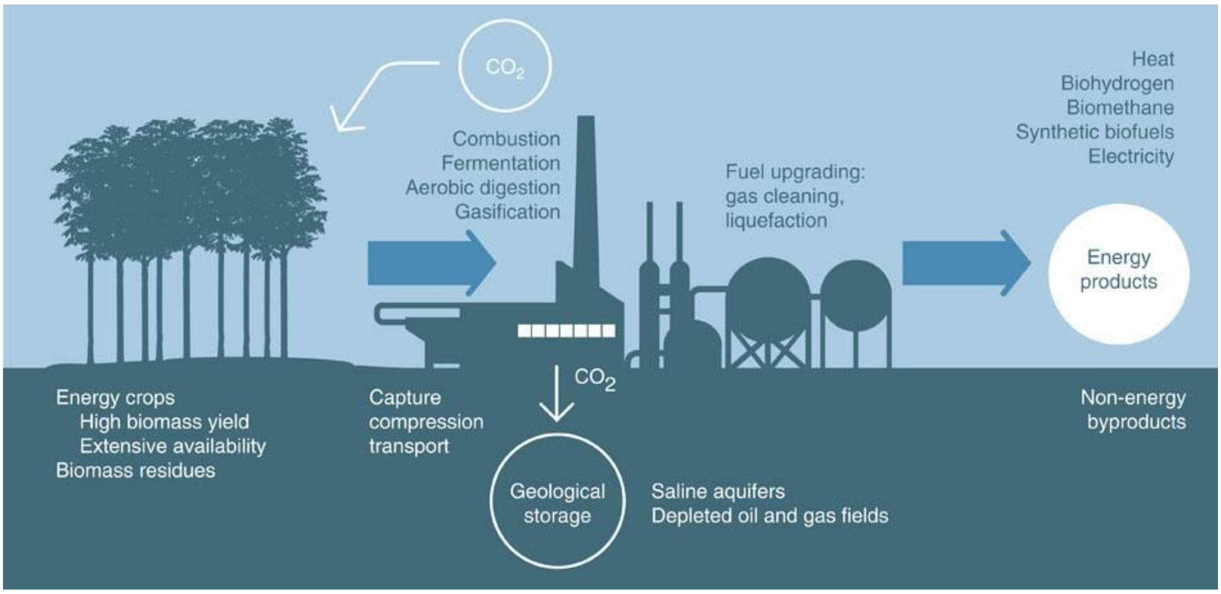



***Figure 6 Biomass resources and utilization*** **(adapted from Greanandgrowing, 2017)**

Biomass has a wider range of potential uses than wind and solar energy. Like the latter two, it can be converted into electricity. It can also be burned with coal to reduce sulfur emissions and to help with the transition from fossil fuels to renewable energies. It can be used by itself to generate electricity by being converted to fuel, which can then be combusted to make steam or power a gas turbine or used in fuel cells for direct conversion to electricity. A variety of biomass fuels, in the form of synthetic gases like ethanol, biodiesel, a combination of alcohol and vegetable oil, animal fat or recycled cooking oils, can also be used to power the transportation sector, which is currently a significant source of greenhouse gases (Hossen *et al.*, 2017).

Worldwide production of energy from biomass has the potential to provide for over half of the world's energy needs by 2050 (Bhattacharya, 2017). For electricity production, however, biomass may be best suited for areas that are not highly populated and do not require the high-intensity use of energy. The potential for high-intensity use is much lower than other fossil fuels because of the amount of land required to grow biomass crops. It could be especially useful in handling municipal waste, although it is uncertain how much energy could truly be afforded by waste in highly populated areas. In Portugal the production of electricity by biomass represents about 6% in 2015 (DGEG/PORDATA, 2017c).

#### *2.1.2.6 Ocean Energy: Wave and Tidal*

Ocean energy is caused by the gravitational pull of the moon, the sun, and Earth (creating tides), by the wind (creating waves), and by temperature variations in the water. Medieval times saw a reasonably broad use of ocean waterwheels across Europe (Lopez et al., 2013). While many processes for the utilization of ocean energy have been considered, only a few methods have received the most research and development attention. The two most developed types of ocean energy technologies are the wave and tidal.

Many technologies are currently being developed to capture wave energy. These technologies derive energy from surface waves or pressure variations beneath the water. Wave energy can be transformed to electricity in both onshore and offshore applications. Offshore applications are located in water that is over 80 m deep. The motion of the waves is used either to power pumps that create electricity or to pressurize water that then turns a turbine. Onshore applications make use of the power of breaking waves on the shore. Three technologies have been developed to utilize this energy source:

a) Point absorber: In comparison to wavelength, they usually are significantly smaller regarding to the diameter. Unlike other devices, point absorber collects the energy in all directions through its movements (Ocean Power Technologies, 2017). These devices generate electricity from the bobbing or pitching action of a device, by converting the up-and-down pitching motion of the waves into rotary movements, or oscillatory movements (depending on specific device). An example of this is OPT's PowerBuoy 150 kW technology (**Figure 7**-a).
b) Attenuator: These types of Wave Energy Collectors (WEC) are long structures compared with the wavelength and are placed in parallel with respect to the wave direction. In essence, they "attenuates" the amplitude of the wave. Attenuators are designed by a series of cylindrical sections linked together by flexible hinged joints that allow these individual sections to rotate relative to each other. **Figure 7**-b shows Pelamis 750 kW prototype converter which is a typical example of this type of devices (Pelamis Wave Power, 2017).
c) Terminator: These devices are similar to Attenuators, as they are also long structures (European Marine Energy Centre, 2017). However, these are placed perpendicular to the predominant direction of wave propagation and, in essence, "terminate" the wave action (**Figure 7**-c).

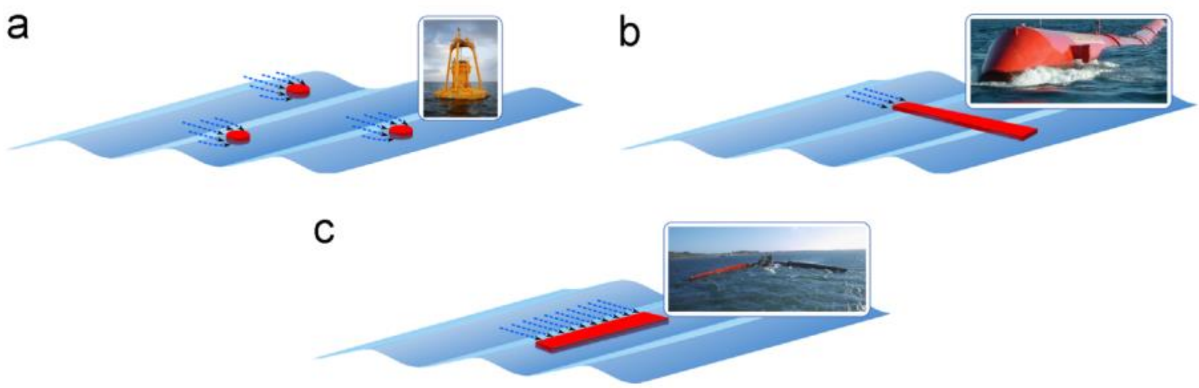



***Figure 7 Wave Energy utilization*** **(Lopez et al., 2013)**

Tidal energy technologies utilize ocean currents and the difference between low and high tide to generate electricity (Shevkar & Otari, 2015). The difference must be high enough, over 5m, to create electricity. As in wave power, three main technologies have been revealed to convert tidal power into electricity:

a) Barrage or dam forces tides into an area where they come into contact with a turbine and power a generator (**Figure 8**).
b) Tidal fences which are apparatuses that look like giant turnstiles. The turnstiles, spun by ocean currents, are capable of generating electricity at rates as high as winds with very high velocity.
c) Tidal turbine (similar to wind turbines or river turbines) are situated underwater in an arrangement that is similar to that of a wind farm. At about 15m in diameter, they are ideal in waters that range from over 20 to 30 m in depth.

The only large-scale operation using tidal energy is in La Rance, France (Khan *et al.*, 2017), and there is no tidal energy production in Portugal.

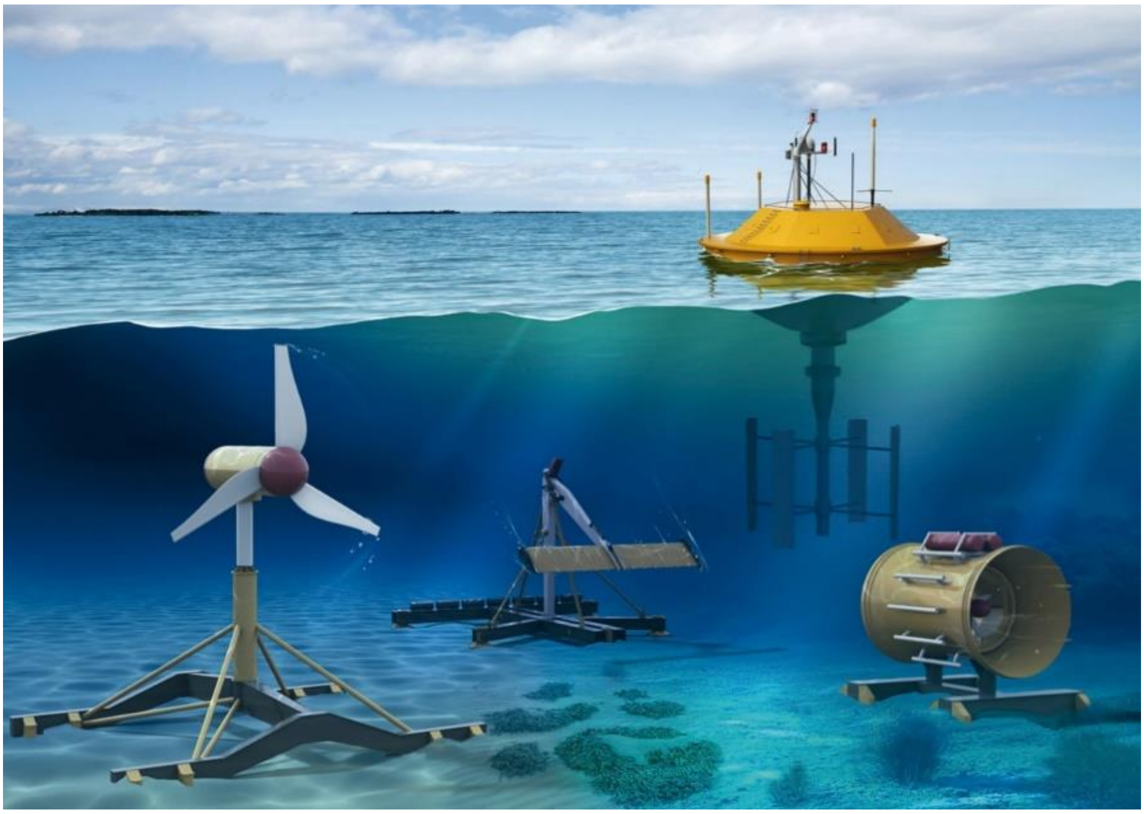


***Figure 8 Tidal energy utilization*** **(adapted from The Irish Times, 2017)**

Moreover, there are other technologies already developed and working in Europe such as molten salt energy harvester, wave energy converter, and biofuel technologies.

### **2.1.3** Environmental Impact of Construction

Construction has a great responsibility for the negative environmental impact. To better understand this impact, the construction activities consume 50% of the natural resources, only in the construction phase (UN, 1992). According to UNEP-IETC (2003), construction activities contributed over 35% of total global $CO_2$ emissions – more than any other industrial activities and buildings account for more than 40% of total energy consumption, and the construction sector as a whole is responsible for approximately 40% of all human-produced wastes.

In order to mitigate these facts, Kibert (1994) established five principles on which construction activity should be based from the outset:

- Reduce resource consumption;
- Reuse resources whenever possible;
- Recycle materials at the end of the building's life and use recyclable resources;
- Protect natural systems and their function in all activities;
- Eliminate toxic materials and by-products at all stages of the life cycle.

The United Nations (UN) deals with environmental problems in global level in case of global warming, depletion of the ozone layer and depletion of natural resources which affect humankind (Blom, 2010). The UN attempts to initiate global action on sustainable development through international agreements. At the UN Conference (UN, 1992) on Environment and Development (Earth Summit) in Rio de Janeiro in 1992, an action agenda (adopted by 178 governments) was set for international, national, regional and local actors in every area of the environment that is affected by human beings. Specific agreements have been reached on reducing global warming, protecting the ozone layer and preserving abiotic (non-living) natural resources. The Kyoto Protocol (UNFCCC, 1998), the agreement on reducing greenhouse gas emissions, which cause global warming, had been signed by 84 signatories and ratified by 191 parties in June 2010. To protect the ozone layer, which is at risk mainly from CFCs, a UN agreement, the Montreal Protocol (UNEP, 2000), on banning the use of CFCs has been signed and ratified by 191 Nations. Since the Montreal Protocol came into force, the depletion of the ozone layer appears to have come to a halt. Lastly, the UN has developed activities in Africa to manage and protect reserves of natural resources.

The United Nations Environmental Program (UNEP) and the European Commission (EC) have identified the building sector as a key factor in reaching the Kyoto Protocol targets. The building sector consumes an estimated 30-40% of energy worldwide and around 36% in the European Union (EU): the non-residential sector accounts for 8.7% and the residential sector for 27.5% of the total. In 2008 the EC proposed a recast of the EPBD (Energy Performance of Buildings Directive) to include all buildings undergoing refurbishment and minimum performance requirements for building components. Furthermore, from 2020 all new buildings will have to comply with 'nearly zero' energy consumption standards. The definition of 'nearly zero' can be set by the individual Member States. The European Parliament approved the EPBD recast in May 2010 (EU, 2010).

The goal of green building and sustainable architecture is to use resources more efficiently and reduce a building's negative impact on the environment. Zero energy buildings achieve one key green-building goal of completely or very significantly reducing energy use and greenhouse gas emissions for the life of the building. Zero energy buildings may or may not be considered "green" in all areas, such as reducing waste, using recycled building materials, etc. However, zero energy, or net-zero buildings do tend to have a much lower ecological impact over the life of the building compared with other 'green' buildings that require imported energy and/or fossil fuel to be habitable and meet the needs of occupants.

### **2.1.4** Sustainable construction techniques

The sustainable construction consists, in practical terms, on the application of the concept of sustainability in all phases of the building life cycle (from idea to dismantling, obviously passing through the design phase), which translates to what is called architecture bioclimatic - which consists on the application and use of materials and substances with sustainability criteria, *i.e.* without endangering their use by future generations. It represents the concept of optimum energy management of high technology buildings through the capture, accumulation and distribution of renewable energy passively or actively, and the integration of landscaping and use of indigenous and healthy materials, ecological criteria and eco-construction (Neila Gonzalez, 2004). Bioclimatic strategies are a set of rules or measures of a general nature designed to influence the shape of the building as well as its processes, systems and constructive components. The strategies to be adopted in a particular building or project should be selected; taking into account the climatic specificity of the site, the function of the building and, consequently, its occupation and operation, with the aim of promoting good performance in terms of climate adaptation (Gonçalves & Graça, 2004).

Before explaining the typical sustainable construction techniques, a technical site study of the project has to be fulfilled. Then the related sustainable techniques are introduced based on the site available resources and situations.

*2.1.4.1 Solutions based on the project site*

A technical review of the site enables the architect to improve the possibilities for solar access, daylight penetration, and natural ventilation through natural means, minimizing the impact on the location and the surrounding areas. At the macro-scale, the general climate of the region sets the stage with appropriate temperature, humidity, precipitation, cloudiness, wind speed, wind direction and sun path. Typical maxima and minima are used to define the amount of rainwater that must be drained away; the directions of favorable and unfavorable winds; when solar radiation should be invited or avoided and from which direction; and when the temperature moves outside the comfort zone. At the local scale, this climate will be modified by particular conditions. Drainage will affect humidity; industrial smoke or waste gasses may reduce solar radiation; and topography will affect wind speed.

2.1.4.1.1 Sun light radiation and potentials

To calculate the capacity of solar energy in a location, we have to find the peak sun hours. One sun hour is the measure of the amount of solar radiation received by a surface perpendicular to the sun, for one hour, at sea level (Kacira *et al*., 2004). It is expressed normally in $kWh/m^2/day$. The most productive hours of sunlight are from 9:00 a.m. to 3:00 p.m., around solar noon. When the sun is directly overhead, the distance from the sun to the solar panel is the shortest. Thus, the light is passing through the least amount of atmosphere with the least amount of reflection, and the panel produces the most available energy. In the morning and evening, the sun is lower in the sky, and sunlight passes through thicker atmosphere, and has a greater angle of reflection. During these periods the panel receives less sunlight to make power. The figure 9 shows world peak sun hours. Lisbon is situated in a region with 4-4.9 peak hours (**Figure 9**). Therefore, Lisbon has a significant potential for solar energy.

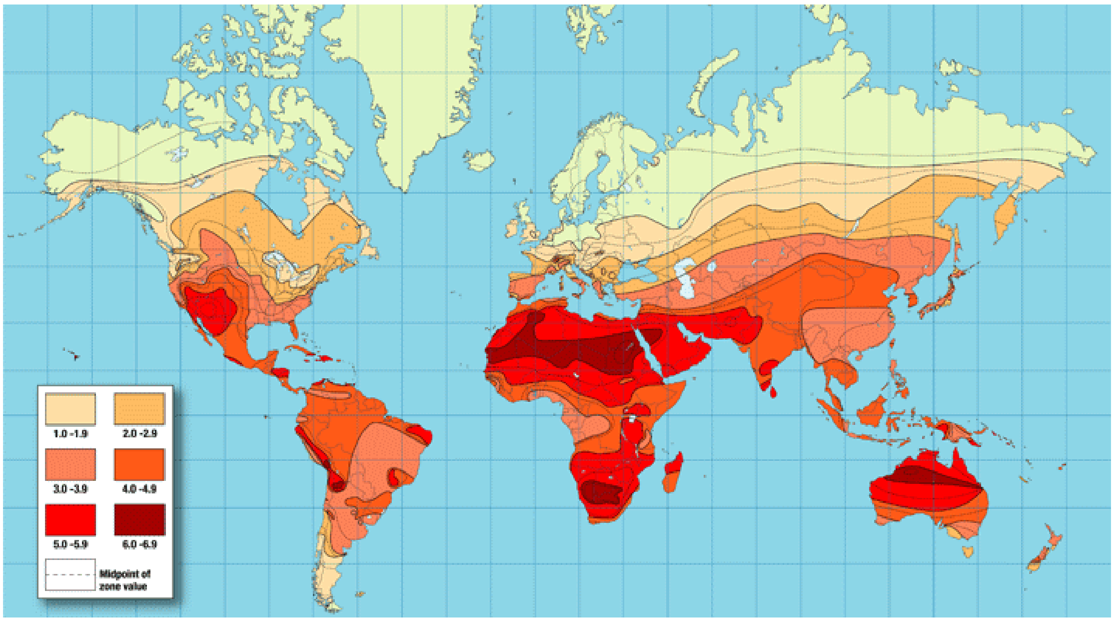



***Figure 9 Peak sun hours in different regions*** **(adapted from Global Peak Sun Hour, 2017)**

Photovoltaic technology represents a decentralized electricity generating system that can help a building provide its own energy requirements directly from sunlight. An important focus of photovoltaic applications is their integration into the building envelope. Integrating PV panels into façade cladding systems is relatively straightforward and more cost effective than in the past. Photovoltaic modules in the form of building components can take on many additional functions as they are developed from glass modules to thin film cells, and applied to metal foils and plastic films to provide flexibility and semi-transparent modules. Photovoltaic roofs in which the photovoltaic panels themselves serve as the roofing material, are increasingly seen in Europe. Based on the newest technologies in photovoltaic materials and the following map, the variation of the annual average solar radiation on tilted panels changes between 200 kWh/m² (Norway) and 2600 kWh/m² (Saudi Arabia). In Lisbon the annual average solar radiation is 2200 kWh/m² (see figure 10).

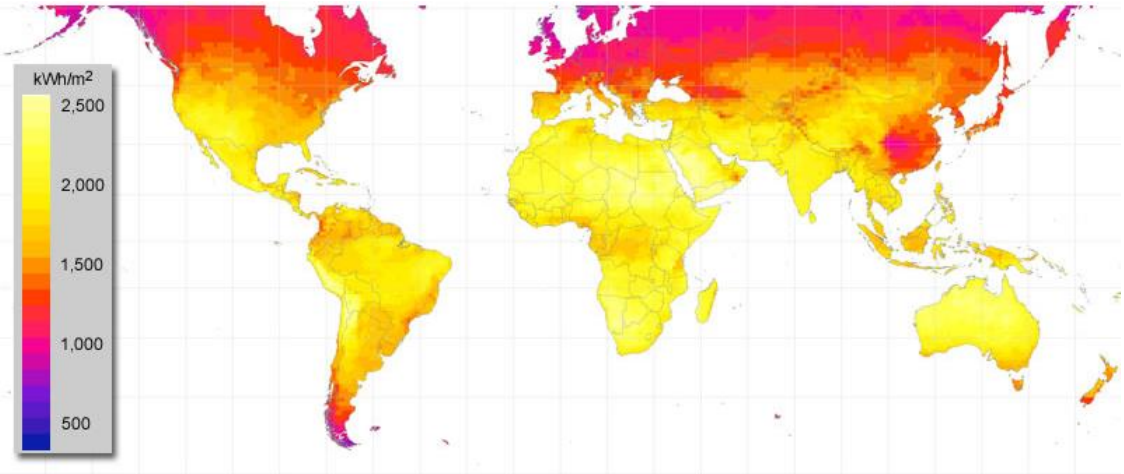
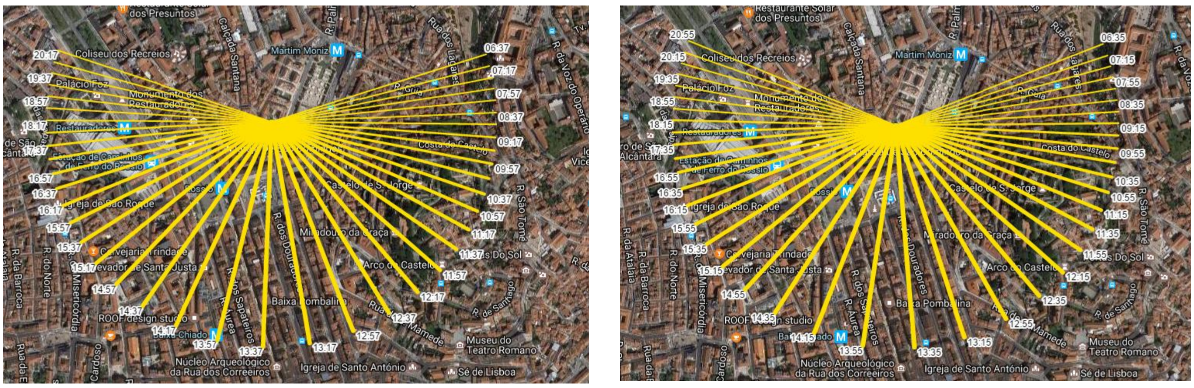


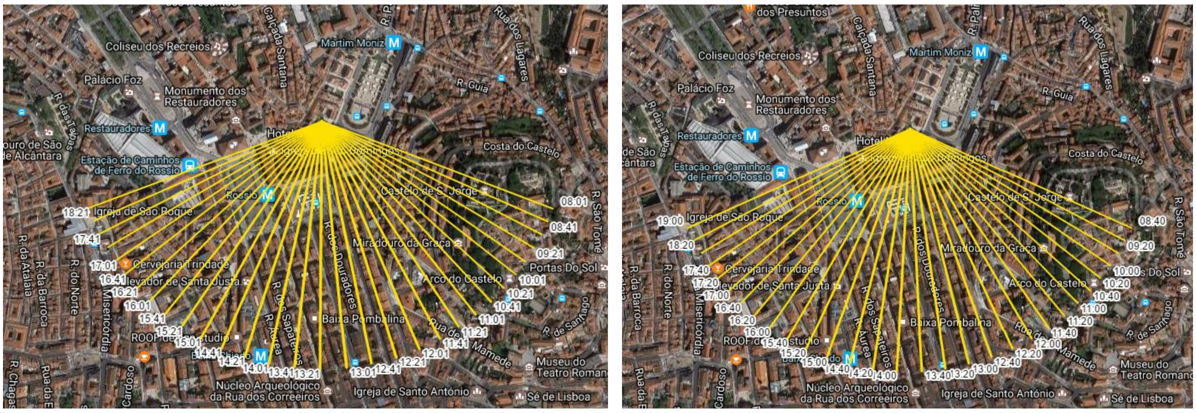

***Figure 10 Annual average irradiation on tilted panels in different regions*** **(adapted from Annual Solar Irradiance, 2017).**

2.1.4.1.2 Sun direction

For the Martim Moniz area (Lisbon) the sun light direction and hours in project land is presented in **Figure 11** (time zone is considered as UTC+1) and Table 1.



Spring Summer




Autumn Winter

***Figure 11 Sun shine hours in Martim Moniz area*** **(adapted from andrewmarsh, 2017)**

***Table 1 Sun direction in Martim Moniz area*** **(adapted from timeanddate, 2017)**

| | Spring | Summer | Autumn | Winter |
|---|---|---|---|---|
| Sunrise Azimuth: | 70° | 66° | 108° | 112° |
| Noon Altitude: | 66° | 69° | 37° | 34° |
| Sunset Azimuth: | 290° | 294° | 252° | 249° |

Based on the equation below we can calculate the annual solar energy production per square meter PV panel for Lisbon (247.5 kWh/m$^2$):

$$E = A \times r \times H \times PR$$

Where, $E$ is the absorbed energy in $kWh$, A is the area of PV panel (m$^2$), $r$ is the PV panel yield (usually 15%), $H$ is the annual average irradiation on tilted panels (**Figure 10**), and PR is the performance ratio, coefficient for losses (range between 0.9 and 0.5, default value= 0.75) – see Table 2.

***Table 2 Rough calculation for solar energy capacity in our case study***

| | |
|---|---|
| E = Energy (kWh) | 247.5 |
| A = PV panel area (m²) | 1 |
| r = solar panel yield | 0.15 |
| H = Annual average irradiation on tilted panels (shadings not included) | 2200 |
| PR = Performance ratio, coefficient for losses (range between 0.9 and 0.5, default value = 0.75) | 0.75 |

2.1.4.1.3 Optimum Tilt of Solar Panels by Month

Based on the sun radiation directions in different months during a year, the Table 3 gives the angles in which the solar panels have to be set for working in maximum efficiency. **Figure 12** shows the seasonal change of solar panels.

***Table 3 Optimum tilt of solar panels by month(angles are in degrees from vertical direction)***

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 35° | 43° | 51° | 59° | 67° | 74° | 67° | 59° | 51° | 43° | 35° | 28° |

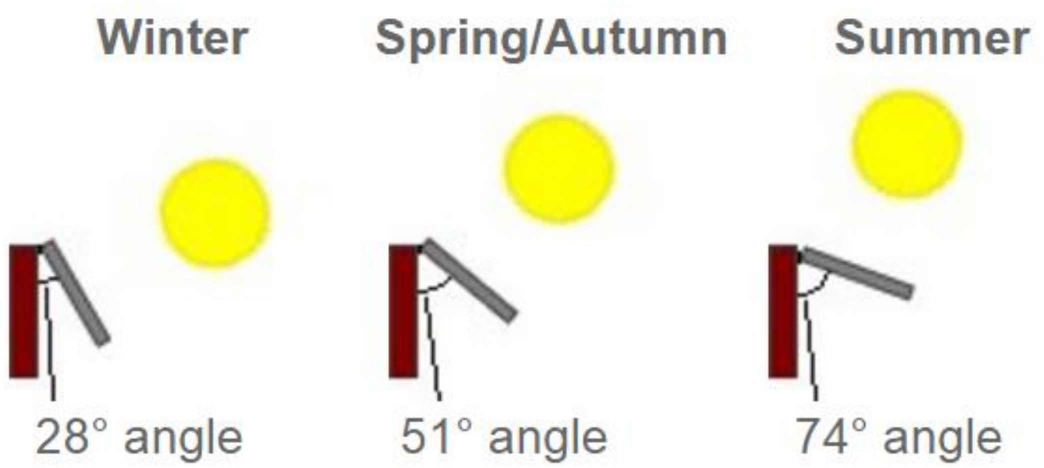



***Figure 12 Seasonal solar panel angles for maximum energy absorption*** **(adapted from solarelectricityhandbook)**

2.1.4.1.4 Wind Rose direction

The local wind pattern gives an appropriate data for sustainable ventilation system design. The wind rose graph of Lisbon (**Figure 13**) shows how many hours per year the wind blows from the each direction. For example, SW means that wind is blowing from South-West (SW) to North-East (NE).

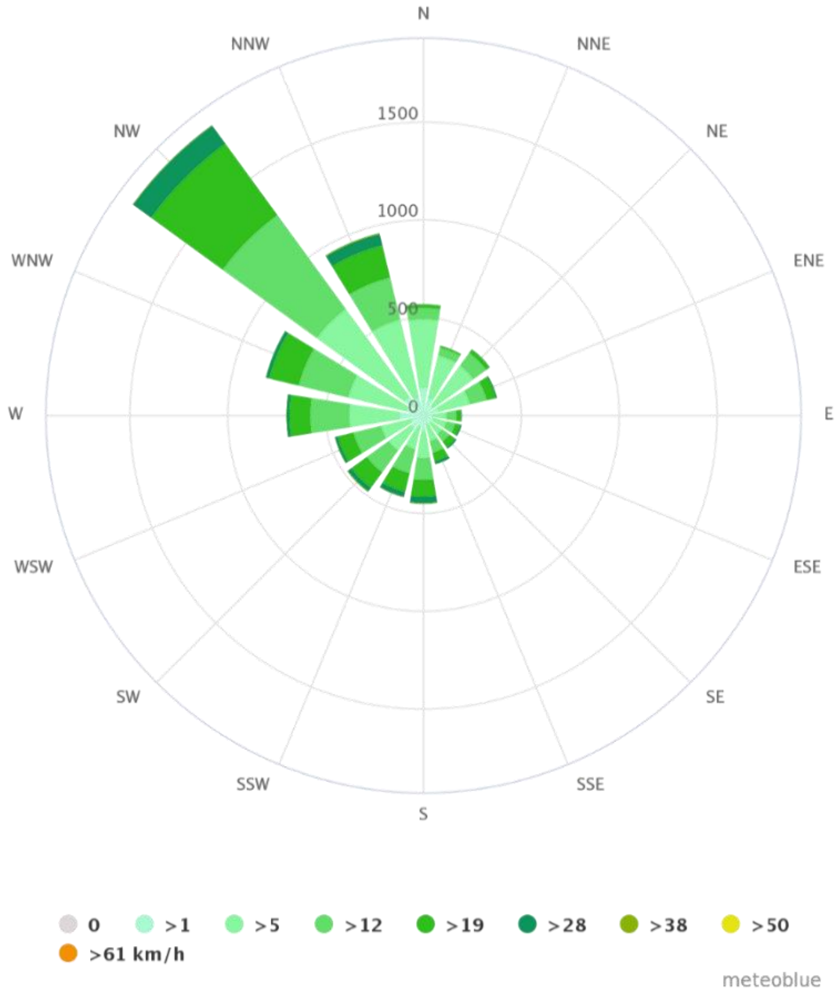



***Figure 13 Wind rose direction in Lisbon*** **(adapted from windfinder, 2017)**

The key points in site wind analysis are as follows:

- Wind speeds on the crest of a hill may be 20% greater than on flat ground
- At night time the cold air will tend to move downwards on exposed slopes, while the air is warmer higher up
- A slight wind even on calm days is characteristic of sea-coasts or lake shores
- Deep valleys or long straight avenues can funnel and accelerate wind speeds
- High buildings can create localized high wind speed and turbulence

2.1.4.1.5 Raining statistics

The statistics (weather-and-climate, 2017) show the following data about rain fall in Lisbon:

- Lisbon has on balance 753 mm of rainfall per year, or 62.8 mm per month.
- On average there are 113 days per year with more than 0.1 mm of rainfall (precipitation) or 9.4 days with a quantity of rain, sleet, snow, etc. per month.
- The driest weather is in July when an average of 5 mm of rainfall (precipitation) occurs.
- The wettest weather is in November when an average of 114 mm (4.5 in) of rain (precipitation) occurs.

2.1.4.1.6 Rain water harvesting

To study the rain water harvesting in Martim Moniz area, the first step is to investigate the monthly and annual rainfall. **Table 4** shows the precipitation data, number of wet days and percentage of sunny hours.

***Table 4 Weather statistics in Lisbon*** **(adapted from weather-and-climate, 2017)**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Precipitation (mm) | 110 | 111 | 69 | 64 | 39 | 21 | 5 | 6 | 26 | 80 | 114 | 108 | 753 |
| Precipitation (Liters/m²) | 110 | 111 | 69 | 64 | 39 | 21 | 5 | 6 | 26 | 80 | 114 | 108 | 753 |
| Number of Wet Days (probability of rain on a day) | 15 (48%) | 12 (42%) | 14 (45%) | 10 (33%) | 10 (32%) | 5 (17%) | 2 (6%) | 2 (6%) | 6 (20%) | 9 (29%) | 13 (43%) | 15 (48%) | 113 (31%) |
| Sunny (Cloudy) Daylight Hours (%) | 54 (46) | 56 (44) | 57 (43) | 66 (34) | 69 (31) | 73 (27) | 85 (15) | 85 (15) | 74 (26) | 68 (32) | 57 (43) | 55 (45) | 69 (31) |

On the other hand, we have to define the rain water harvesting process (**Figure 14**). Rainwater harvesting means capturing and storing rain that falls on-site (usually on roofs). It is generally used for irrigation and toilet flushing or other greywater[1] uses, though it can also be used for drinking water if it is adequately treated.

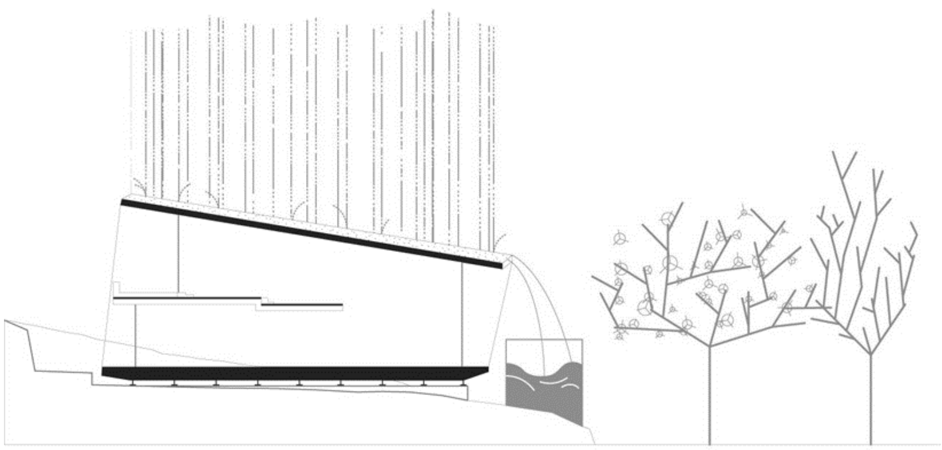


***Figure 14 Rainfall harvesting system*** **(adapted from archdaily, 2017)**

Capturing rainwater can be a valuable way to reduce or even eliminate a building's use of municipal potable water, without requiring reductions in water use by occupants. However, it is of course more effective in rainy climates than dry ones. Rainwater harvesting systems are measured by their area for collecting water and the volume of water they store. Simple rainwater collection systems have three main elements: the roof or other catchment area, the

[1] Graywater is water polluted with dangerous chemicals or microbes (Toilet and shower waters) and could not be directly used for drinking.

storage tank(s), and the gutter and other piping that directs the water from the catchment area to the tank. The storage of water at the base of the building or underground only produces environmental benefits when the water is later pumped to low levels, consuming slight energy. When there is a need to use water on upper floors, water should be stored at the highest levels to take advantage of gravity and reduce pumping energy consumption.

Meanwhile, we can employ Permeable Paver technology in corridors and bare spaces in the green areas and gardens. Permeable paving is a range of sustainable material and technique for permeable pavements with a base and subbase that allow the movement of storm water through the surface (**Figure 15**). In addition to reducing runoff, this effectively traps suspended solids and filters pollutants from the water.

***Figure 15 Permeable Paver technology*** **(adapted from Wikipedia, 2017)**

Finally, to calculate the amount of water that we can store annually, we have to know the projected horizontal area of the roofs including the areas we can employ water drainage technology in the yard. In this case study, the area of the roof is 1280 $m^2$. So the area that we have for harvesting water is 1280 $m^2$. Based on the rainfall statistics, **Table 5** shows the amount of water we conserve during each month.

***Table 5 Harvested water by month***

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm (l/$m^2$) | 110 | 111 | 69 | 64 | 39 | 21 | 5 | 6 | 26 | 80 | 114 | 108 |
| $m^3$ | 140.8 | 142.1 | 88.3 | 81.9 | 49.9 | 26.9 | 6.4 | 7.68 | 33.2 | 102.4 | 145.9 | 138.2 |

### *2.1.4.2 Bioclimatic strategies*

The bioclimatic chart (see **Figure 16**) is a powerful representation that combines several factors and considers their interaction and effects on thermal comfort (Givoni, 1998). The Building Bioclimatic Chart has two components: thermal comfort area and "boundaries of climatic conditions within which various building design strategies and natural cooling systems can provide comfort" (Givoni, 1992).

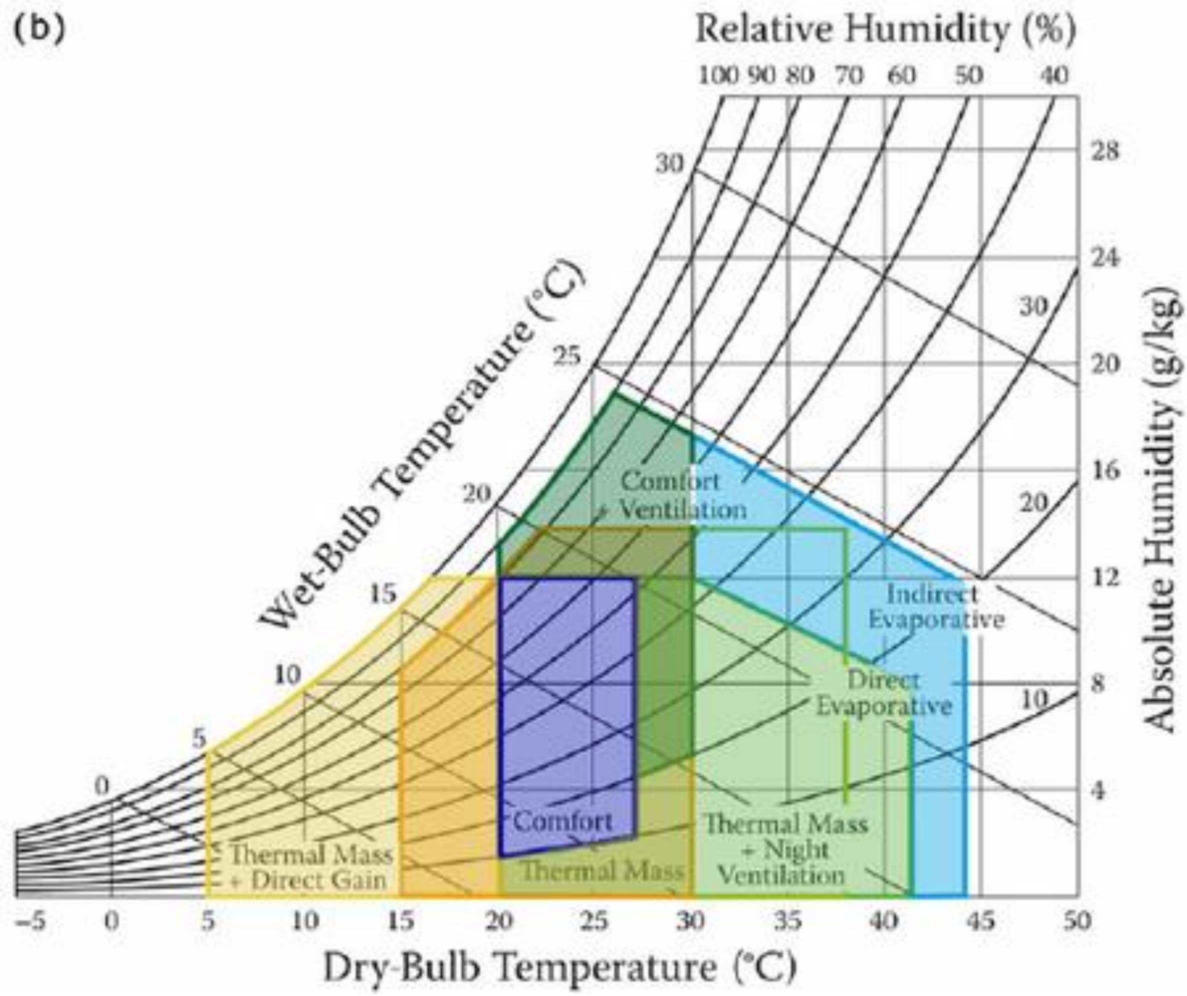



***Figure 16 Baruch Givoni's Bioclimatic Chart*** **(Schiavon *et al*., 2014)**

2.1.4.2.1 Warming Strategies

In the regions corresponding to aggressive winter climates (area Thermal Mass+Direct Gain of figure 16) the energy losses by conduction must be reduced by the application of insulating materials in the constructive elements (walls, roofs, floors and glazing). Also must be reduced the energy losses by infiltration and the effect of the action of the exterior wind by the window frames with an efficient seal and protection of dominant winds with vegetation and choice a good location for the building, if possible. A different type of strategies in the passive solar systems for heating is promoting solar gains (Gonçalves & Graça, 2004).

2.1.4.2.2 Cooling Strategies

In the regions corresponding to tropical and equatorial climates, or temperate of maritime influence (area Comfort Ventilation of figure 16) the more suitable strategy is promoting natural ventilation. There are good examples of the application of this strategy in the houses of light inertia typical of the vernacular architecture of the tropical regions and in the cooling systems by ventilation (Gonçalves & Graça, 2004).

In the regions corresponding to all climates that require cooling (areas Thermal Mass, Thermal Mass+Night Ventilation, Direct Evaporative and Indirect Evaporative of figure 16) the solar gains must be reduced. Additionally, to this strategy, promoting evaporative cooling in the regions corresponding to dry temperate climates and climates of arid and very dry desert (areas

Thermal Mass, Thermal Mass+Night Ventilation of figure 16). Good examples of these strategies can be found in Middle Eastern architecture (Gonçalves & Graça, 2004). Additionally, to the solar gains reduction, in the regions corresponding to all warm climates of continental influence with high thermal amplitude (area Direct Evaporative of figure 16) the strategy more suitable is promoting radiation cooling. There are good examples of this strategy in all the architecture of the Middle East and also in Southern Europe, particularly in Portugal (Alentejo and Algarve) and Spain (Andalusia) (Gonçalves & Graça, 2004).

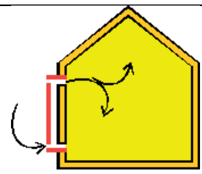
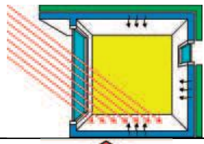
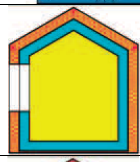
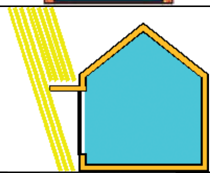
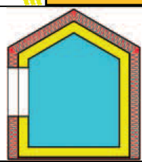
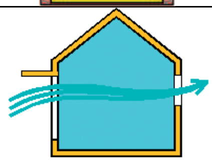
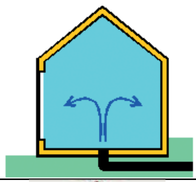
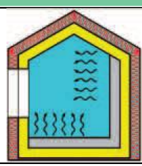
#### 2.1.4.2.3 No strategies required

The Comfort area of figure 16 corresponds to the neutral zone of comfort for the human where the conditions of outside climate are close to the conditions of comfort. The architecture should avoid excessive solar gain and require that no other serious errors in ventilation and conduction heat exchange (Gonçalves & Graça, 2004).

#### 2.1.4.2.4 General strategies for Lisbon

In **Table 6** different bioclimatic strategies based on Baruch Givoni's chart are indicated for Lisbon and similar climate regions (Gonçalves & Graça, 2004).

***Table 6 Bioclimatic strategies for buildings in Lisbon*** **(Gonçalves & Graça, 2004)**

| Season | Bioclimatic Strategies | Passive Systems | |
|---|---|---|---|
| **Winter - Heating season** | Promote solar gains | All gain systems are suitable for the types of more convenient buildings |   |
| | Reduce losses by heat conduction | Insulate envelope |  |
| | Promoting Strong Inertia | Heavy walls with insulation by outside |  |
| **Summer – Cooling season** | Reduce solar gains | Shade glazing |  |
| | Reduce heat conduction gains | Insulate envelope |  |
| | Ventilation | Transverse ventilation (night) |  |
| | | Underground pipes |  |
| | Promoting strong inertia | Heavy walls with insulation by outside |  |

### **2.1.5** Sustainable materials

There is a large family of materials which can be employed in the construction of buildings, and careful selection of environmentally sustainable building materials is an important means of incorporating sustainable design principles into buildings. To perform a complete analysis of the environmental impact of all the components and materials in a building would be prohibitively time-consuming and expensive. However, a responsible architect should weigh up environmental considerations alongside other criteria. To do this the architect requires an understanding of the environmental impact of materials (Mumovic & Santamouris, 2013), and that is what this chapter aims to provide.

There are various issues that should be thought by any architect who is concerned about the environmental impact of the materials that will go into the building. For elements applied in quantities of 250 kg or less, consider the following points:

- Impact of the material's composition: habitat destruction, toxins released;
- Lifespan of material;
- The ultimate destination of the material after building's life. Re-use is better than recycling, which is better than incineration or landfill;
- Reduction/separation of construction waste and avoidance/careful disposal of toxic waste.

For highly weighted materials, consider all the above issues, but also:

- The nature of the resources involved: renewable or non-renewable, scarce or abundant;
- Emissions of $CO_2$ (in kg) during production or, if information is not available, embodied energy (in kWh/kg);
- How far and by what mode(s) the material will be transported, and associated emissions/energy use.

#### *2.1.5.1 Life cycle design*

Life cycle review of a material includes all phases of the process from collecting or extracting raw materials, manufacturing, transportation and installation, to end of life reuse or disposal of the material or component (Bribián *et al*., 2011). The nature of life cycle can be organized into three distinct phases: manufacturing, use and disposal/reuse. Many diverse methodologies have been developed for carrying out life cycle analysis (LCA) of materials and products, which has resulted in challenges in evaluating and comparing the environmental performance of materials and products.

#### *2.1.5.2 Wood*

Wood is a major constituent of a wide range of products used in a building. In most cases, similar comments can be made for the wood-derived portion of these products as for wood itself that it is even less easy to be certain of the wood's provenance. Many products, such as chipboard, fibre-board and even synthetic structural beams, make use of waste off-cuts and chips of timber. While this is no guarantee that the timber itself comes from a sustainable source, it does at least ensure that the timber is being used efficiently. Plywood, however, makes use of large-dimension timber which is unlikely to be sustainably produced. The other components of wood products vary widely.

#### *2.1.5.3 Straw and plant fibers*

Straw consists of the stems of grain crops such as wheat, oats, barley, rye, and rice left over after the grain has been harvested. Straw may seem an unlikely candidate for a building material, but it is steadily growing in popularity because of its ready availability, low environmental impact, and excellent insulating properties, due to low thermal conductivity

(0.045 to 0.070 W/m.K) (EDF, w.d.). Straw and other plant fibers are also used as the raw material for panel products, which can be used in a wide range of applications. Reeds, straw, and other plant stems are also a traditional roofing material.

##### *2.1.5.4 Soil and stone*

Soil (and clay) was one of the first building materials and is still one of the most widely used. Even today, one-third of the human population resides in earthen houses. In developing countries, this figure is more than half. Land is used in building in several different ways. Perhaps the simplest is where it is 'puddled' with water and other ingredients and the building's walls are built up by hand without forms.

Stone forms the basis of traditional architecture in many places and is still widely used. It is particularly useful for its high thermal mass, strength, and durability (depending on hardness) and beauty. Stone is non-renewable but abundant, although some types are scarce. However, the greatest environmental impact of stone is likely to be due to haulage. The natural and traditional solution to this problem is to use locally quarried stone.

##### *2.1.5.5 Cement and concrete*

Portland cement is generally used in Europe and it is a mixture of chemical compounds of calcium, silicon, and oxygen with some iron and aluminum. The exact mix determines the properties of the cement. About 5% gypsum (calcium sulphate) is then added. Because of the high temperatures required, the process is highly energy-intensive. In addition, the chemical reaction producing lime from calcium carbonate (calcining) releases carbon dioxide. A key strategy of the environmentally aware architect should be to minimize the amount of cement used. The other major environmental consideration in the use of concrete is disposal. Concrete forms about half of all waste from construction and demolition. It can often be crushed for reuse as aggregate, but re-use has been too rare.

##### *2.1.5.6 Brick, Tile, and Ceramics*

Ceramics such as brick, tile and sanitary ware are made by baking clay at high temperature. Clay is a highly abundant, although non-renewable material. Clay quarrying can have a detrimental impact on local environments, but the main environmental impact of ceramics is due to the fuel burnt during the firing process. The energy used in this process will vary, however the energy contained within a typical brick has been calculated as 3.00 MJ/kg and up to 9.00 MJ/kg for glazed ceramics (Brophy & Lewis, 2011).

##### *2.1.5.7 Glass*

Glass refers to materials, usually blends of metallic oxides (predominantly silica) which do not crystallize when cooled from the liquid to the solid state. It is the non-crystalline or amorphorus structure of glass that gives rise to its transparency. Glass is made from silver sand, sodium carbonate and sulphate, all of which are nonrenewable resources but none of which are scarce. The manufacturing process is highly energy-intensive, with typically 0.85 kg of $CO_2$ per kg of glass produced (Brophy & Lewis, 2011). The environmental impact of the glass is outweighed by its importance in influencing daylighting and thermal performance. Glass is generally recyclable, and the small proportion traditionally recycled is increasing.

##### *2.1.5.8 Metals (Aluminium, Cooper, Steel, Lead, and Zinc)*

Metals are obtained by mining, which is often detrimental to the local environment through large-scale physical alteration and toxic emissions. Most mine sites require expensive rehabilitation after closure before the land can be reused. Although metals are a non-renewable resource, they are generally recyclable, and construction and demolition waste should be separated in order to facilitate this. Recycling saves a significant proportion of the energy used in the extraction process.

### 2.1.6 Examples of sustainable constructions

In this part of the project a series of successful examples in sustainable building construction are presented. In each case main parameters of the building including the energy saving efforts are described by German Energy Agency (2006).

#### *2.1.6.1 LA VOLA*

The environmental services company LA VOLA is the first Spanish Green Building Partner. The building is situated in Manlleu, Barcelona. With a total area of 1.100 $m^2$, the building hosts approximately 50 persons (**Figure 17**). A reduction of the total primary energy demand of the building by more than 30% has been obtained compared to a conventional office building due to an optimized building envelope, a highly efficient lighting system, low consuming electrical equipment, use of solar energy for DHW and electricity production, high efficiency heat and cold production systems, and a centralized energy management system permitting to adapt the energy consumption to the thermal load of the building at each moment.

***Figure 17 LA VOLA green building*** **(adapted from Green Building, 2006)**

Measures performed:

- Optimized building envelope (ventilated facade, automated movable shading devices, high insulation levels, green roof...)
- Heat and cold distribution by radiant floor
- Heat recovery systems and air preheating in greenhouse facade
- Cross-ventilation with interior patio
- Air quality control sensors for optimized air renovation
- High efficiency lighting system and low consuming lifts
- Photovoltaic and solar thermal energy production
- Centralized energy management system

Energy savings:

- Primary energy savings compared to conventional office building: 31%
- Electricity consumption reduced: 27%
- Gas consumption reduced: 40%
- $CO_2$ savings: 13.500 kg/year

*2.1.6.2 Municipal Swimming pool of Vale Fundão*

The Câmara Municipal de Lisboa (CML), the local authority responsible for the management of the Lisbon municipality, became the first Portuguese Green Building Partner in July 2006. The candidature of CML was based on a set of 5 new municipal swimming pools (e.g. Piscina Municipal do Vale Fundão (**Figure 18**)) built in 2005/2006 with a total area of 14.185 $m^2$ and designed to integrate energy efficient technologies, including renewables (solar thermal), as well as a modern energy management system.

***Figure 18 Municipal Swimming pool of Vale Fundão*** **(adapted from Green Building, 2006)**

Measures implemented and energy savings:

- Integration of 120 thermal solar collectors that will guarantee two-thirds of hot water demand including facilities and services (restaurant, showers and general public toilet).
- Installation of electronic ballasts to achieve lighting electricity savings of about 30%.
- 4-way heat pumps (free-cooling system) to heat the main hall, allowing reductions of approximately 35% in the consumption of electric energy and thermal energy.
- Incorporation of passive solar measures (double glazing, external shading devices, etc.), resulting in energy savings of more than 30%.

*2.1.6.3 Nursery School Philipp-Körber-Weg 2 in Nuremberg*

The City of Nuremberg, which became the first German Green Building Partner in March 2006, received the Partner status for the refurbishment of the 19th-century administration and Cantina building of the Nuremberg abattoir. In the conversion of the 3-storey building to a nursery school with an information center (**Figure 19**), the energetic standard of the building in neo-renaissance style has been enhanced significantly.

A reduction of the total primary energy demand by more than 80 % has been achieved due to an optimized building envelope, a very efficient lighting system and the installation of a highly efficient condensing boiler.

The building's energy demand is 32% below the German building regulations and even 5% below the requirements for comparable new buildings. The thermographic analysis, which was performed after the refurbishment measures were completed, proves the excellent thermal standard of the building.

***Figure 19 Nursery School Philipp-Körber-Weg 2 in Nuremberg*** **(adapted from Green Building, 2006)**

Measures performed:

- Installation of an efficient gas condensing boiler for heating and warm water supply (80 kW, 350-liter storage tank).
- Floor heating in ground floor and first floor with single room regulation, steel panel radiators in the top floor.
- Installation of energy saving fluorescent tubes with electronic ballasts.
- Installation of wood frame windows and doors with enhanced thermal protection.
- Interior insulation of all outer walls.
- Insulation of the cellar ceiling, outer walls and roof.

Energy savings:

- Primary energy savings compared to before the renovation: more than 80%
- Heating energy demand reduced: 75%
- $CO_2$ savings: 80.000 kg/year

In this section different renewable energy resources that are available in Portugal and their utilization method are described. Also, different potential environmental impacts of the sustainable buildings are studied. Then a variety of sustainable architecture techniques and materials are presented based on Lisbon geographic situation and available resources. In the next section, after defining the historical and social situation of Martim Moniz area, different characterizations of the zone are explored to see the available renewable energy resources in the area and suitable methodologies for sustainable design. Then a sort of potentials and constraints are studied to see the challenges for the sustainable construction in the area.

## 2.2 The potential for sustainable constraint

The main target of Portugal like other countries in Europe is to minimize construction impacts, use fewer resources, be healthier during the operation phase and also be suitable for recycling and minimization of waste (OECD, 2003). The constructions should even be designed for long life and adaptability to different uses. This concept embraces a big number of aspects such as design and management choice of materials, building performance as well as interaction with urban and economic development and management. Different approaches are followed according to the local socio-economic context; in some countries, priority is given to resource use (energy, materials, water, and land use), while in others social and economic issues are the more determining constraints (**Figure 20**).

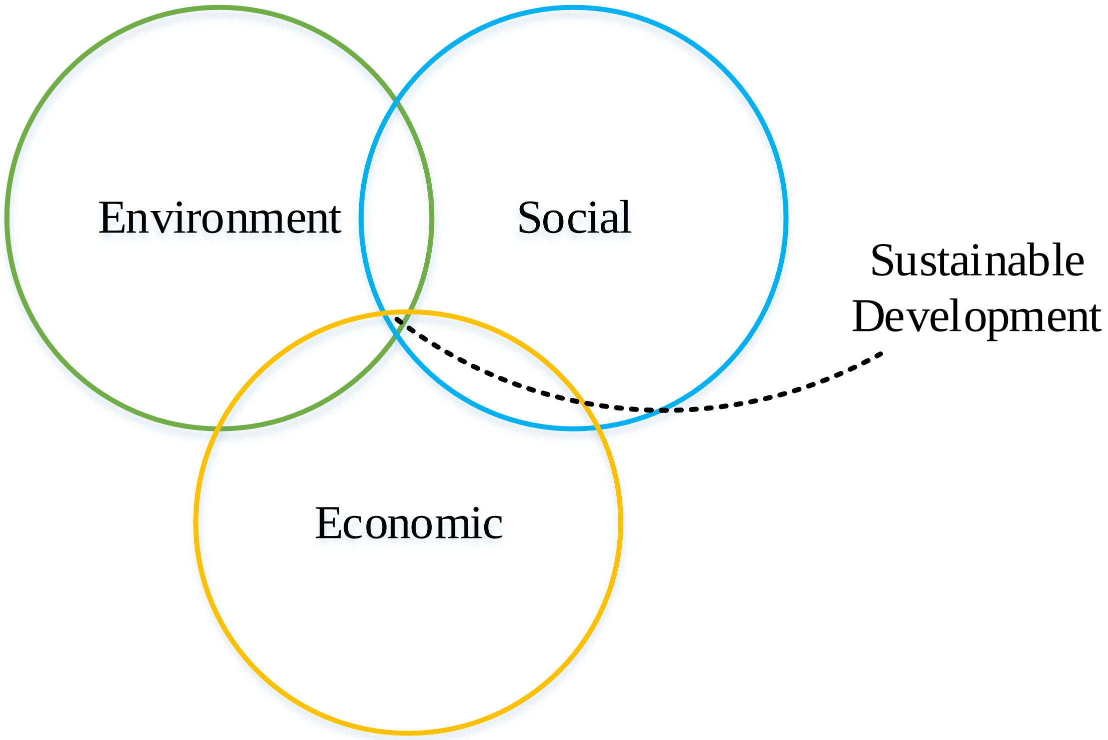



***Figure 20 Constraints in sustainable development of constructions*** **(OECD, 2003)**

In this thesis the main restrictions are divided into specific sub-domains to discuss each potential and constraint in advance. In **Table 7** different constraints in sustainable building development are presented and discussed below.

***Table 7 Constraints in sustainable building development***

| Environmental | Social | Economical |
|---|---|---|
| Energy | Health | Management |
| Water | Comfort | Cost |
| Material | Contest | Information |

Waste

### 2.2.1 Energy

Oil prices' hikes are creating new markets for other renewable sources that are mentioned in the first section of this thesis. Also on January 2008 EU issued a proposal for a Renewable Energy Directive with a target of a 20% share of renewable energy sources and a 10% minimum target for biofuels in transport, to be achieved by 2020 (Amer & Daim, 2010).

As it can be seen in the **Figure 21** Portugal must provide 31% of its energy consumption trough renewable energy by 2020. This percentage is nearly achieved in 2015 by 29%. Also, tackling climate change doesn't mean only energy efficiency and renewable fuel (zero energy buildings) but even building materials and products with low and renewable embodied energy.

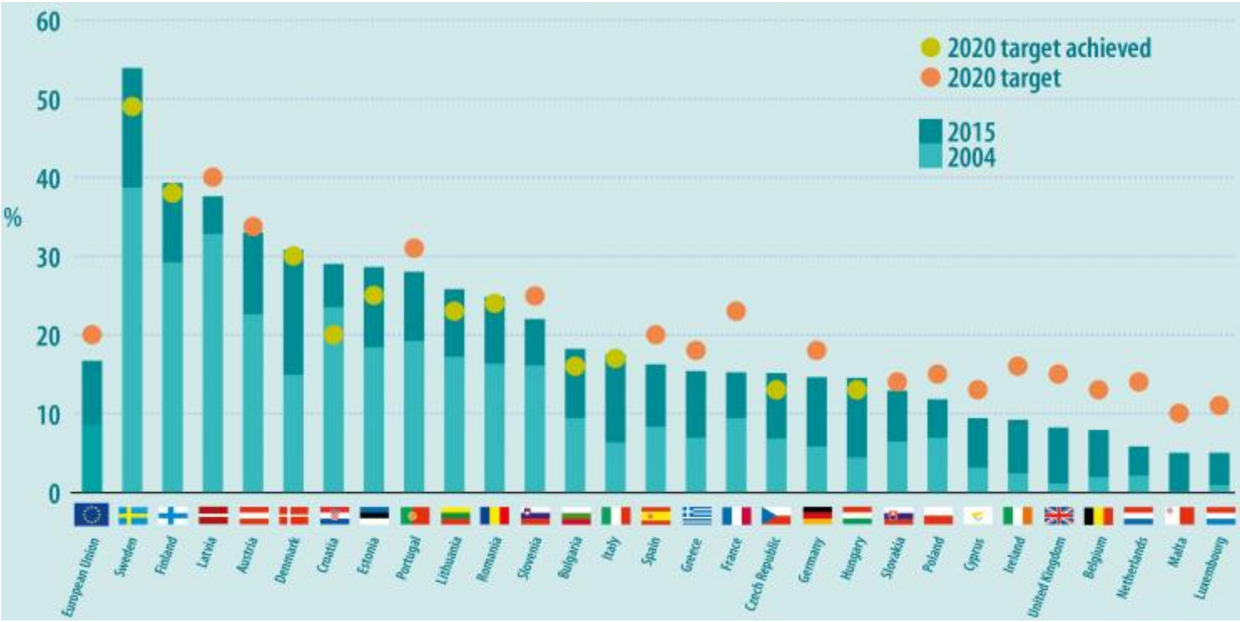



***Figure 21 Renewable energy targets in Europe*** **(adapted from CleanTechnica, 2017)**

### 2.2.2 Material

One of the main constraints in sustainable building design is the material and their environmental impact on the region. Three highly used materials in buildings in Portugal are wood, steel, and concrete. The **Figure 22** shows the embody energy pin buildings with different materials (Peuportier *et al*., 2016).


***Figure 22 Embodied energy content in buildings with different materials*** **(Peuportier et al., 2016)**

On the other hand, energy is not the only important embodied effect. Some environmental impacts are almost entirely a function of product manufacturing. **Figure 23** presents net $CO_2$ emission of materials during their life cycle (Huovila, 2007).

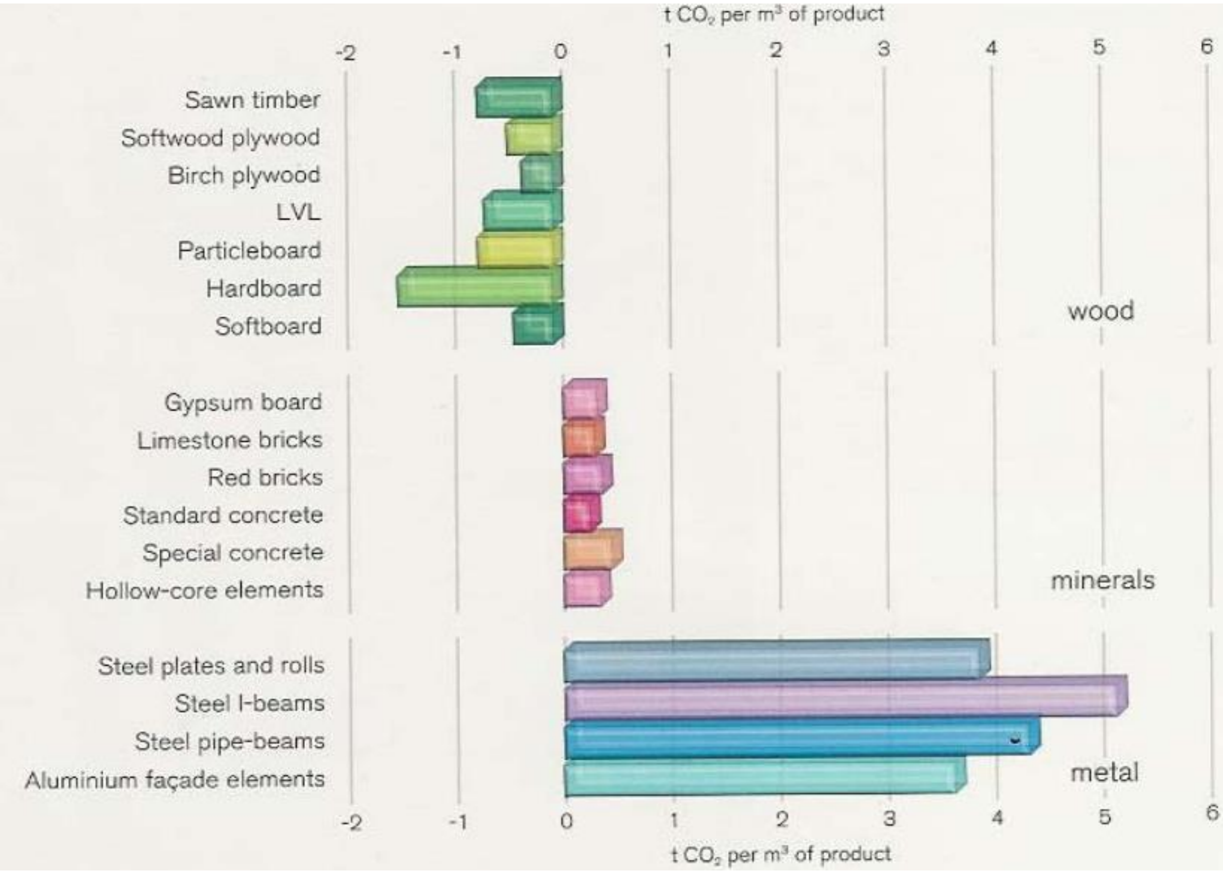



***Figure 23 Net CO2 lifecycle emission*** **(Huovila, 2007).**

### 2.2.3 Water

The amount of water consumption in construction is the major constraint in water stressed countries (Kibert, 2016). Portugal and other Mediterranean countries because of their hot and long summers are considered as water shortage regions in Europe. Also, water resource management in sustainable construction plays an important role. **Figure 24** shows the water consumption and pollution based on the materials used in the construction.

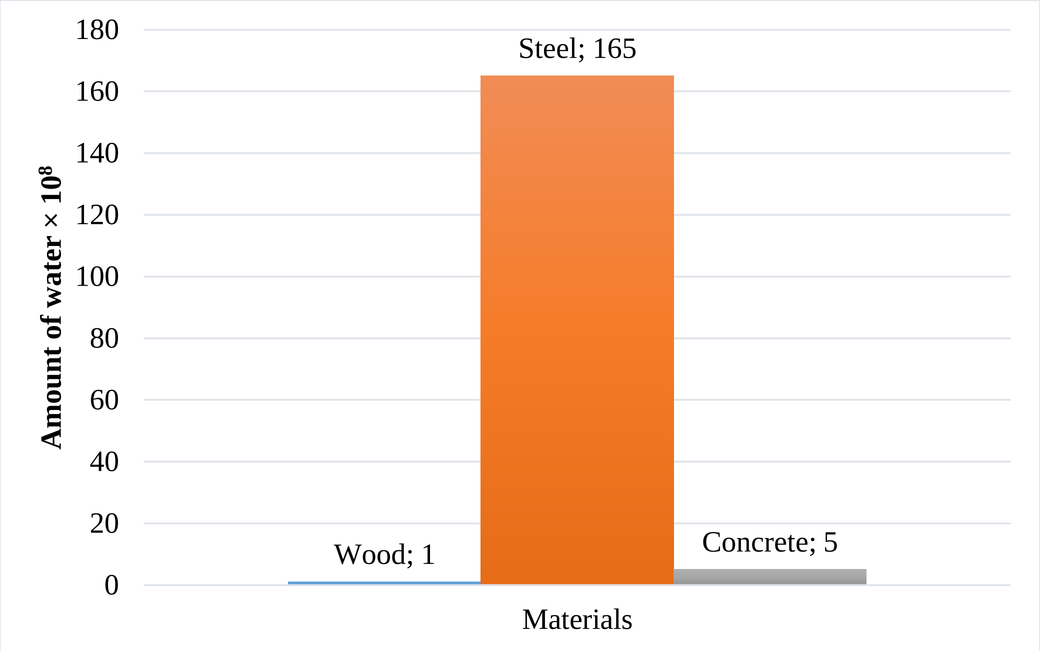



***Figure 24 Water consumption and pollution based on the materials*** **(Peuportier et al., 2016)**

### 2.2.4 Waste

Waste is always one of the main constraints of sustainable construction while it has its own restriction based on the region and building type. Prefabrication systems can assume quality in the building sector, avoiding volumes of construction wastes and hazards on building sites. They request a more accurate design but they help in reducing building costs. Transport of heavy and big elements can be logistic constraints in Martim Moniz region with low accessible areas. Wood can be reclaimed from decommissioned buildings and re-used directly, an increasing niche activity, or chipped into low-grade uses or burned as fuel.

### 2.2.5 Heath and Comfort

Many researches support the benefits to human health and productivity from green features such as day-lighting, increased natural air ventilation, moisture reduction, and the use of low-emitting materials, interior finishes and furnishings. There is an increasing demand of labeling system for construction materials in EU. Poor indoor air quality exacerbates asthma, allergies, and the spread of influenza, and is the cause of sick building syndrome and contributes to Legionnaires' disease. **Table 8** indicates potential savings based on considering health and comfort constraints in sustainable buildings in Europe.

***Table 8 Potential savings based on considering health and comfort constraints (Pfeffer, 2010)***

| Building improvements | Savings (b€/year) |
|---|---|
| Reduced allergies and asthma (based on a reduction of 8 to 25% of medical costs) | 3-6 |

| | |
|---|---|
| Reduced sick building syndrome symptoms (based on 20 to 50% reduction and 2% productivity improvement) | 15-45 |
| Increasing productivity by comfort related improvements (based on 0.5 to 5% increase in worker performance) | 30-240 |

### 2.2.6 Social Contests

Direct environmental impacts that result from the construction of buildings include greenhouse gases and other air emissions, water use, and discharge, storm water runoff, impacts related to building materials, solid waste, indoor and outdoor air quality. Secondary impacts are generally associated with building product lifecycles, infrastructure development, and transportation systems. So, general contests of sustainable building are: air pollution, bio-tech farming, consumer design, deforestation, end angered species, globalization, global warming, green washing, hazardous waste, overconsumption, poverty, transportation, urban sprawl, waste management and water pollution (Huovila, 2007).

### 2.2.7 Management and costs

A building's initial construction costs typically may represent only 20 to 30% of the building's entire costs over its useful life (Feige *et al.,* 2013), underscoring the need to consider even the operating costs through the whole life of the building and not only for the first 10 years. The main constraint here is that developers are not interested in paying for green features when the benefits will be passed on to the new owners but they can recoup the additional costs in the sale price or project income realized. In this case, the insurance sector can link their premiums to adoption of responsible management.

A survey by the World Business Council for Sustainable Development (Popescu *et al.* 2012) finds that real estate and construction players estimate the green additional cost at 17% above conventional construction, more than triple the true average cost of approximately 5%. Many key decisions are taken on the basis of the lowest costs instead of quality, safety and environmental criteria and life-cycle costs. There is a need to offer solutions at the advantage of both the clients and the industry. "Economical Most Advantageous Tender" (EMAT) and Life-Cycle Costing should be included.

In Germany, the government supports the construction of passive buildings with 100% mortgages at fixed interest rate below the rate bank (Ecofys, 2013) Similar arrangements are applied to renovations. The level of financial support for renovation is given on a sliding scale according to carbon footprint achieved. It is to be hoped that this example could be followed on an environmental assessment basis.

### 2.2.8 Information and knowledge

While certified products and chain-of-custody continue to gain traction with architects and builders, these have not yet been incorporated into current building codes. A problem in certification is that for example, all green building programs require certification of wood. This is the case despite well-known environmental issues associated with the sourcing of all materials. It also makes sense that when certified construction materials are required or given preference as a matter of public policy, such certification or similar requirements should be uniformly applied to all materials.

In this section a historical and social study of the zone are fulfilled and general characterizations of the zone are presented. Also, different challenges (Economical, Environmental, and Social) in sustainable design are defined. In the next section of this thesis the proposal of the project including the site analysis, conceptual design of the project, schematic proposal, and urban project are explained in advance.

# 3 CASE STUDY

## 3.1 Martim Moniz Square

Taking into account the present dynamics that take place in the Martim Moniz[2] Sq. (**Figure 25**), reflected on the importance of ethnographic practice in the perception and understanding of the everyday circumstances. The aim of this section is to present some usage scenarios and appropriation of space, in addition to having contributed to the registration of the Martim Moniz Sq. in the social and urban map of Lisbon and also contributed to the invention of a geography of resistance particularly incident in the modern city. There are four reasons that stimulate this reflection:

1) the geographic and historical situation of this square, located in the historic center of Lisbon but relatively young in its current configuration, compared to the other squares in the city;
2) the effective building of the square as a result of a controversial set of social and urban policies for that area of the city;
3) the representative nature of this place, together with two shopping centers nestled in its surroundings in an attempt to build a multicultural identity image for the city of Lisbon;
4) the role of the court under a set of related political demonstrations, for example, to claim labor rights and legality for immigrants, but also with movements linked to extreme right.

***Figure 25 Martim Moniz square*** **(Flicker, 2017)**

### 3.1.1 History of the square

The Martim Moniz square is linked to the history of Lisbon until the mid-sixteenth century, it was centered in the vicinity of that area, away from the Tagus river (Lisbonlux, 2017). This

[2] Martim Moniz (died 1147) was a Portuguese knight of noble birth and famous figure in the Siege of Lisbon in 1147. According to the legend, Martim Moniz was a knight participating in the Christian invasion force, led by King of Portugal, D. Afonso Henriques, in the siege of Lisbon, during the reconquer (Menezes, 2009).

area was built slowly, allowing the expansion of the confined territory of Mouraria which has this name after the conquest of Lisbon to the Moors in 1147.

The urban structure where currently fits the square, remained practically unchanged until the first half of the twentieth century (Menezes, 2009). Not even the earthquake of 1755 caused significant destruction in the area. Between 1930 and 1960, the Mouraria neighborhood becomes focus of an urban policy promulgator a “civilizing urbanism” and diffused from the perspective of “cleaning and beautification” that sought to renovate that area of the city with a view to modernization, radically altering the their social, cultural and urban dynamics. This intervention period was marked by the completion of major public works inspired by a rectilinear design in which the existence of the ancient city was seen as an interruption to progress.

Between 1946 and 1949 (Menezes, 2009), Mouraria saw the Socorro church and the Marquês Alegrete Palace destroyed, followed by the whole block that surrounded them. Instead of the streets that were contiguous, a wide space was born that became known as Martim Moniz.

The destruction perpetrated only spared the core of the neighborhood of Mouraria and the Nossa Senhora da Saúde Chapel (Menezes, 2009). In the late 1940s, the Figueira Sq. was also destroyed, and the market that existed there was provisionally installed in prefabricated pavilions at Martim Moniz. These pavilions remained there until the 1990s, when many of its merchants were moved out of the historic center of the city, being installed in a temporary market in Praça da Espanha (north of Lisbon). The square was occupied by rubbish, waste and car parking, and it was only in the late 1990s, more precisely in 1997, that it was finally transformed into a square (Menezes, 2009).

In 1967 there comes a second urban plan for the city. One of the intentions of this plan was the modernization of the entire area of Martim Moniz from the renewal and revitalization, focusing on automobile accessibility over the idea of a square. Between 1973 and 1975, the newly formed Public Company of Lisbon Urbanization drafted some proposals for urban intervention for that zone-proposals, due to the troubled democratic post-revolution political, were not implemented. It is only in 1982, a public competition organized by the company above mentioned, which prepared the Urban Renewal Plan of Martim Moniz, which included equipment, general trade, food trade, offices, cultural facilities, concert halls, housing and parking (Lisbonlux, 2017). With this plan has changed some local streets sections and built two shopping centers: The Mouraria and Martim Moniz. The remaining plan proposed was forgotten until 1997 when recovered the idea of turning off a square.

The first underground line passing in the area was completed in 1966. The underground station is named Socorro, an allusion to the church that had been destroyed. In off the requalification process of Martim Moniz, the first metro station would also have renovated, reopening in 1997 with a new name: Martim Moniz. The platforms of the station were decorated with figures symbolizing the Christian reconquer: the soldiers and the king who conquered the city from the Moors. The tile panels that decorate the entrance to the underground station, was “redecorated” with graphic symbols that allude to the Arabs, Indians and Africans who stops by those places, passed and still pass.

Since the 1980s, this area became attractive for the development of a wholesale mainly controlled by Indian immigrants, Pakistani, Chinese, Africans, Brazilians, among many other nationalities, places of birth and/or origins. Some of these traders/immigrants were living in Mouraria and/or its surroundings. The social and urban reality of Mouraria has changed markedly, also becoming a place of people, practices, songs, artifacts, different clothes and food.

### 3.2 Characterization of the area

In this thesis an empty space in Martim Moniz area is considered. The latitude and longitude of the project site are 38º42'54.93''N and 9º8'14.40''W, respectively. One of the major constraints is the high slope of the site. The building designed is faced to Palma St. (at 12.5 m of height from sea level and contiguous to Martim Moniz Sq.), while its backed to Arco da Graça St. (at 24.5 m of height from sea level). The available area for construction is 2034 m$^2$. As it can be seen in the **Figure** the land is faced to the south east with 30 degrees of trim from west-east line.

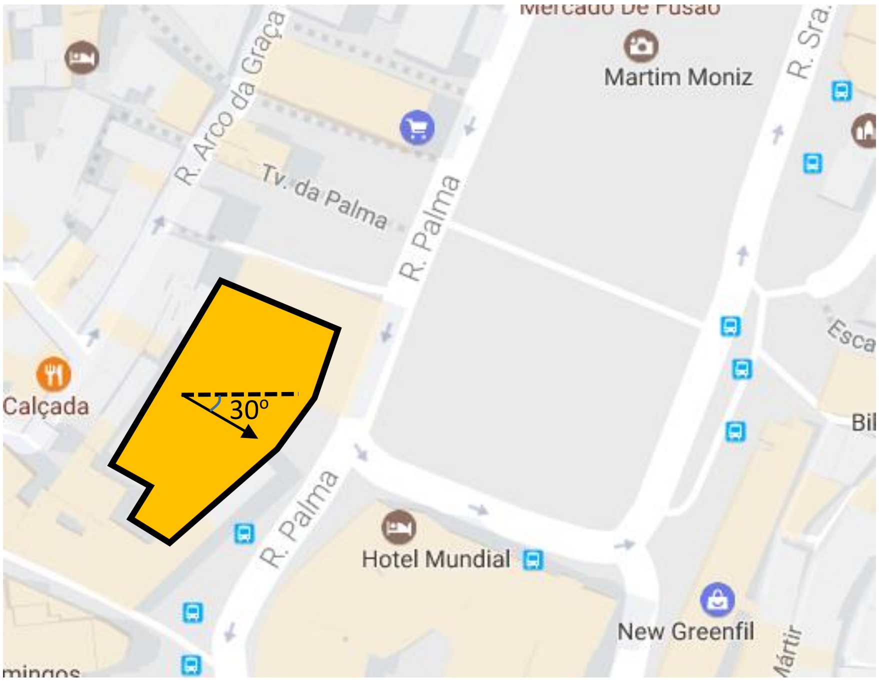



***Figure 26 Geographical characteristics of the project area.***

The site is surrounded by commercial and residential buildings. The buildings in front side of the site are commercial and in the back and the other two sides are residential. Additionally, the frontal building has 15 m of height in north east side and 13 m in south and south east side, in average. This region of the city is the historical part while the building is neighbor with one remained part of the Cerca (wall) Fernandina[3] and the building has a considerable view to the St. Jorge Castle.

On the other hand, technical properties of the area such as sunlight direction, wind rose direction, and precipitation data are indicated in section 2.1.3 (Sustainable construction techniques). Based on the topographical data of the site and sunlight direction in **Figure 11** the building has to take some design constraints to take advantage of natural lighting and passive heating conditions. Also **Figure 13** shows the wind rose direction which indicates that most of

[3] The Cerca Fernandina was built between 1373/75 by D. Fernando, given the defensive inefficiency of the old Moorish fence (CML, 2017a).

the winds are coming from the back of the building (North west side) while a small portion of mild winds blow from front side of the building (South east side). The amount of annual precipitation based on **Table 4** is 753 l/m$^2$ while the top raining month is November. So, the rain water drainage system including water reservoir in the basement/top of the construction can provide desired water for green space which is one of the main issues of this project. More details of the construction are indicated in section 3.

# 4 PROJECT PROPOSAL

## 4.1 Site analysis

After the Lisbon conquering the first two small local councils (called *Assembleias de Freguesia*) in the area are St. Vicente and Sta. Maria dos Mártires, where the Crusaders camped and made cemeteries during the siege, hence the term 'martyrs.'

The administrative organization of Lisbon (AR, 2012; 2015) created a new map of the city and is based on a strategy of modernization of municipal governance model, decentralizing administrative skills to the *Assembleias de Freguesia*, regarding: (i) maintenance and cleaning of public spaces, (ii) management and maintenance of equipment, (iii) proximity licensing and (iv) housing and community intervention. This new model implied a reduction of the number of *Assembleias de Freguesia* from 53 to 24 and a geographic reorganization of Lisbon.

Santa Maria Maior is a result of increased mixture of nationwide municipality. Actually, Sta. Maria Maior (**Figure 26**) meets ancient councils of Lisbon historical center by adding twelve old assemblies (Castelo, Madalena, Mártires, Sacramento, Sta. Justa, Santiago, St. Estevão, S. Cristóvão e S. Lourenço, S. Miguel, S. Nicolau, Sé and Socorro) that share a common long history. The St. Maria Maior council is closely linked to the Lisbon Cathedral, initially St. Maria Maior Church, ordered to build in 1150 by D. Afonso Henriques, three years after conquering Lisbon to the Moors (JF St. Maria Maior, 2017; CML, 2017b).

It represents 2% of the territory of the city but 5% of the buildings, which this indicator means it has twice the density of the city.


***Figure 26 Territory of Santa Maria Maior*** **(CML, 2017b)**

General data of the site (CML, 2017b):

- area: 1,49 $km^2$
- Population (2011): 12,765
- Voters (2012): 12,976
- Accommodation (2011): 10,729

### 4.1.1 Urban Environment

In this thesis the environment of the site is studied in two different parts; (1) Urban hygiene and (2) public places (CML, 2017b).

#### *4.1.1.1 Urban hygiene of Santa Maria Maior*

The growing urban hygiene demands will lead to reorganization of services. In St. Maria Maior council four cleaning stations are responsible for managing the cleaning service of the area: Baixa Chiado, Castelo, Alfama and Mouraria. Specific staff teams have also been created for each area, which promotes speed and quality of action. Also, a group of vans are responsible for the removal of waste and urgent urban cleaning in constant circulation in the neighborhoods of the territory.

On the other hands, some public campaigns are established such as "*A Minha Rua é Linda*" ("My street is beauty") and "*Por um Bairro Melhor*" ("For a better neighborhood"). The goal of first campaign is to make the population to comprehend the message that it is necessary to maintain good hygiene habits in the public spaces, so that everyone can enjoy leaving in cleaner, more beautiful and more pleasant spaces. Also the second campaign is including people in a competition for cleaning the graffiti from the walls.

#### *4.1.1.2 Street furniture and civil facilities of the Santa Maria Maior*

For a proper use of the squares and streets of Santa Maria Maior, the council performs the repair, conservation and installation of urban furniture. This street furniture can be seen is spots such as (**Figure 27**):

- Martim Moniz Sq.;
- Cais do Sodré 21;
- Torre do Jogo da Pela, Cerca Fernandina;
- Praça Dom Pedro IV – Rossio;

Cais do Sodré

Martim Moniz Sq.

Torre do Jogo da Pela

Rossio

***Figure 27 Street furniture of St. Maria Maior territory.***

Also, public laundries and toilets/bathing are installed in different places as follows:

- Páteo 13 bathing in Escadinhas de St. Estêvão;
- bathing of S. João da Praça st.;
- Alfama II bathing/laundry in Palmeira sq.;
- Mouraria 1 bathing/laundry in Cavaleiros st.;
- Alfama 1 laundry in Corvos st.;
- Mouraria 2 laundry/toilets in Rosa sq.
- Sé sq. (next to the kiosk) toilets;
- Carmo sq. (Chiado) toilets;
- Alfama 1 toilets in 13 Regueira st.;
- Alfama 2 toilets in Regueira ao Largo do Peneireiro st.;

- Beco da Corvinha (Miradouro de Santa Luzia, Escadinhas Santa Helena) toilets;
- Ribeira das Naus toilets

The council also promotes civilians with some civil protection lectures and activities, and monthly washing of the streets and gardening in different spots of the site.

## 4.2 Urban Project

The main goal of this project is to create a green public space in the area that increases comfortability for the citizens. Additionally, a health club in the area motivates citizens to participate in social and individual exercises and increases the level of satisfaction for people in the neighborhood. At the same time, the efforts in this project aim to prepare and implement a plan to beautify the city and urban furniture, urban environmental quality and to reduce the greenhouse gas emissions by applying sustainable techniques and renewable energy on the site.

On the other hand, this project aims to promote the citizen's quality of life, with emphasis on improving the welfare and happiness. Also, it has to be indicated that, the project area is close to one of the city's main square, Martim Moniz, where the Metro and bus station are completely accessible and make it easier to use public transportation to have access to this public building. It is not planned to include a car park in the building to discourage the use of the private car, while there is a public underground car park in the Martim Moniz sq.

## 4.3 Schematic Proposal

The development of the morphology of Lisbon passed through the borders of the ‘Cerca Fernandina’, which can be seen today with a major highlight from the São Jorge Castle, passing by Martim Moniz, Tower of ‘Jogo da Pela’, ‘Porta de Santana’ to the ‘Porta de Santo Antão’.

In this project, this area is selected because it represents an opportunity in terms of increasing accessibility and therefore an opportunity to involve the castle in the city as a pedestrian and museological route. From the difficulty in assigning a classification to the set of vacant lots found in this area, this thesis is forced to understand the concept of "what are these spaces in the city?", The absence of construction, the absence of people, the residual space, the makeshift parking and even the most neglected landscaped space seem to fit in the concept. But the definition of this idea is very complex and associated other concepts such as 'Urban Voids' that has to be studied carefully before starting the urban project.

On the other hand, a methodology for evaluating the vacant lots in the zone is carried out and then strategies are defined for the application of the project site in the city performance. These strategies have as their starting point the case study of the project, based on urban mobility as an aggregating element of these new spaces in the existing city and incorporating a character of change and risk associated with uncertainty scenarios, underpinning a new urbanism that is designed in the present city as reflective, participatory, flexible and performant space.

It can be concluded that the greater complexity of the city returns to public spaces, which support processes of reterritorialization, leading to the appearance of empty or transitional urban spaces and their degree of emptiness. This work aims to clarify an epistemological problem that derives from the emergent mutations of the city as well as the public space, and constitutes an opportunity for an important reflection. The combination of full and vacant lots is the best solution for the presence of factors that can make architecture more compatible with the natural structure.

According to project objectives, a public space is going to be developed that includes a swimming pool, gym, restaurant, green space connecting two streets of very distinct altitudes by means of stairs and provides a beautiful view to the S. Jorge Castle.

The available area is 2000 m² and the construction area is 1754.7 m². The building has three floors. The ground floor includes: An office(with the area of 32.73 m² including bathrooms and changing rooms for staffs with the area of 16.42 m²), Cafeteria (Snack bar with the hall area of 60 m² with a 19 m² kitchen, including 9.22 m² of cold and dry storages and 17.76 m² reception in addition with 7.27 m² of bathroom and changing room), Pilates Saloon (with the area of 186.55 m² including a 17.82 m² green patio), Bathrooms and Changing Rooms for clients (with total area of 119.34 m²), SPA Rooms (with total area of 100.29 m²), Physiotherapy Room (with the area of 20.26 m²), Dry Sauna and Steam Sauna (with the area of 12 m² for each), a Swimming Pool (220 m², 11m × 20m) including Jacuzzi (3 m²) and Infant Pool (15 m², 3m × 5m), Cleaning and Equipment rooms (total area of 17.12 m²).

In 1st floor, 532.10 m² is considered for green area while the area of the construction in this floor is 826.22 m². The 1st floor starts with a 44.62 m² area. There are two bathrooms and changing rooms for clients with 20 m² of area for each gender. A physician room with the area of 36.34 m² is considered for clients to visit the doctor. An equipment room with the area of 17.52 m² is considered for spare facilities. A gym with 255.14 m² area with a 17 m² balcony is also designed for the 1st floor. There are two more stores in the 1st floor, one tourism information center 141.38 m² with one bathroom and one changing room. Also, one sport shop with 129.22 m² with one bathroom. The sport shop also includes one storage with 35 m² of area.

In the 2nd floor, a restaurant is designed with 163.72 m² of dining area, 22 m² of lobby, 16.32 m² of reception, 15.13 m² of bathroom and changing room for staffs (each gender), cold and dry storage with 6.71 m² each, and 80.76 m² of kitchen with 11.35 m² of dining room for staffs, 15.13 m² of bathrooms for both genders. In the 2nd floor, also a green space of 292.62 m² is designed. The rooftop with 376 m² of area, is considered for solar panels. 20 units of solar panels will place in the rooftop with total area of 30 m².

In this project, the interior zone materials used are ceramic and wood products for flooring. The exterior zone used is white concrete and mono-lapping for floor covering. Also, some bioclimatic strategies were applied in accordance to the site characteristics.

### 4.4 Conceptual design

The feasibility or evaluation stage is generally considered to be about the physics, use, and viability, rather than how a development is designed or conceived. Concept design (or outline design) requires the architect to engage with the real issues of form and volume, scale and mass and the generic appearance of a building within its surrounding urban context, resolving and encapsulating the principles of the project. Concept design implies an idea, or range of ideas, a development approach, a guiding concept and a design intent. It resolves the issue of 'what' and 'how much' and begins to set the stage for understanding 'how'. Concept design explores the resolution of the brief, implied or set out in the feasibility and assessment stage. The conceptual approach places the quantum of development intelligently on the site.

Conceptual design is an early phase of the design process, in which the broad outlines of function and form of the structure are articulated. It includes the design of interactions, experiences, processes and strategies. It involves an understanding of people's needs and how to meet them with products, services, and processes. Common artifacts of conceptual design are concept sketches and models. **Figure 28** shows a conceptual design of a building.

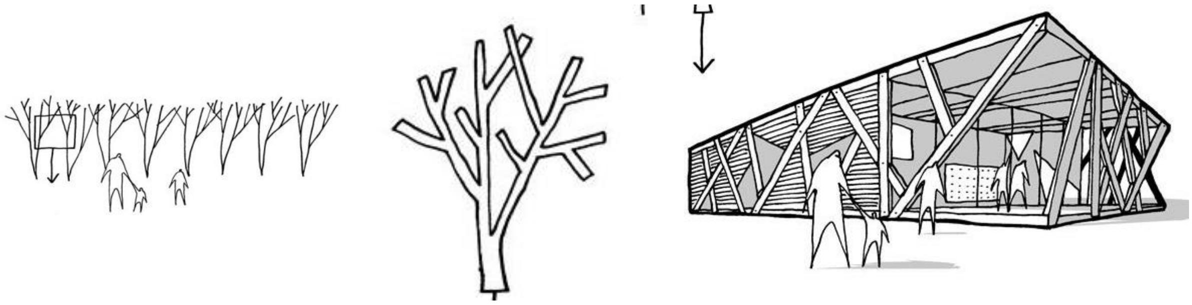
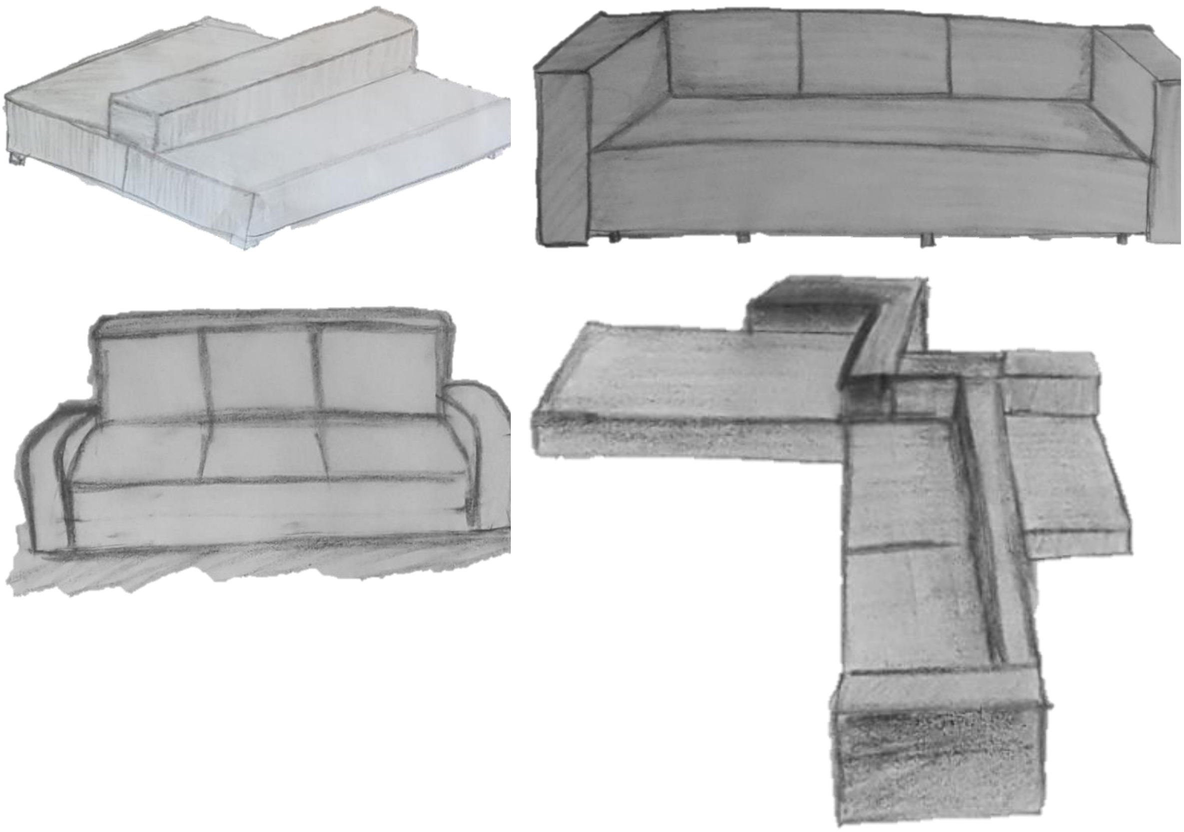
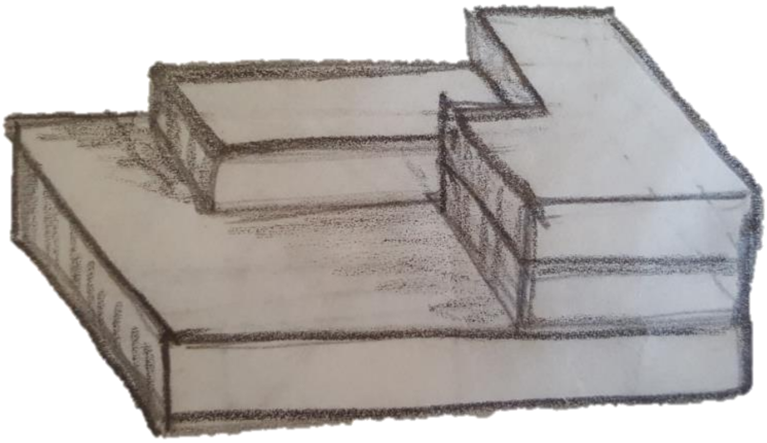


***Figure 28 Conceptual design of a building based on jungle, trees and woods.*** **(Arquitectura, 2017)**

In this project, the main objective of the building is a public health club (including gym, swimming pool, sauna, and spa) and a cafe-restaurant including green spaces and urban furniture. So, the principal concept of the design could be a cubic sofa bed which implies the spirit of relaxation and rest (**Figure 29** (a)). Also, on the site of the project, all the buildings are rigid, rectangle shape with sharp edges and there is no round and curved building in the neighborhood. This constraint together with the needs for urban furniture and green space in this part of the city brought this idea to my mind that a concept design based on furniture and sofa will properly fit in this place (**Figure 29** (b)).



(a)



(b)

***Figure 29 Conceptual design of the project (a) Sketches regarding the sofa concepts (b) Sketch of the primary building design.***

# 5 CONCLUSION

In this thesis, the potential for sustainable building construction in a vacant lot of historical part of Lisbon is investigated. The first step for design of a sustainable building is taken by studying the available renewable energy resources. In this case all the available renewable energy resources in Lisbon and 'Vale do Tejo' region and their utilization methods are studied. Then in the second step environmental impact of the buildings and current regulations for controlling these impacts are presented. In the third step, positive impacts of sustainable buildings such as: resource consumption reduction and reuse of resources, easier material recycle and applying recyclable resources, protection of natural systems and elimination of toxic materials are determined. Meanwhile, sustainable techniques (e.g. passive heating and cooling strategies and rain water harvesting) and materials are studied and different examples of successful sustainable buildings are presented.

After studying the history and culture of the case study region and its morphological and geometrical characteristics, three main challenges (economical, environmental, and social) and their sub-domains are presented.

On the other hand, the main issue in this thesis was to involve the vacant lot of the city in a historical region into an applicable element. In this thesis, this problem is solved through designing a public space based on the major needs of the area into leisure and touristic activities. The main advantage of sustainable design for this region is the less impact that sustainable and green buildings make on their affected neighborhood which in this case the area is highly crowded, touristic and sensitive to pollutions. Through this project the area is furnished by an additional green space and facilitated by a public gym and pool. Also, the accessibility of the streets is increased by the stairway connecting the upper street to Martim Moniz sq. A restaurant is also considered in the design with a view to S. Jorge Castle to increase the visibility of the historical spots in that region.

# 6 REFERENCES


Amer, M., Daim, T.U. (2010). Application of technology roadmaps for renewable energy sector. *Technological Forecasting and Social Change*, *77*(8): 1355-1370.

Andrewmarsh, (2017). Available at: http://andrewmarsh.com/apps/releases/sunpath-on-map.html.

Annual Solar Irradiance, (2017). Available at: http://www.greenrhinoenergy.com/solar/radiation/empiricalevidence.php

AR (2012). Lei nº 56/2012 Reorganização administrativa de Lisboa. *Diário da República*, nº 216/2012, Série I, 8 novembro. Available at https://dre.pt/web/guest/legislacao-consolidada/-/lc/69738118/201712231216/exportPdf/normal/1/cacheLevelPage?_LegislacaoConsolidada_WAR_drefrontofficeportlet_rp=indice (Jan., 2017)

AR (2015). Lei nº 85/2015 Primeira alteração à Lei nº 56/2012 que estabelece a reorganização administrativa de Lisboa. Diário da República, nº 153/2015, Série I, 7 de agosto (pp. 5476-5477). Available at https://dre.pt/application/file/a/69968573 (Jan., 2017)

Archer, C.L., Jacobson, M.Z. (2005). Evaluation of global wind power. *Journal of Geophysical Research: Atmospheres*, *110*(D12).

Archdaily, (2017). Available at: https://www.archdaily.com/office/traverso-vighy

Armstead, H.C.H. (1978). *Geothermal energy: its past, present and future contributions to the energy needs of man*.

Arquitectura, (2017). Available at: http://arquitectura.estudioquagliata.com/tag/cebra

Arshadi, M., Sellstedt, A. (2008). Production of energy from biomass. *Introduction to Chemicals from Biomass*, 143-178.

Bhattacharya, S. C. (2017). State-of-the-art of utilizing residues and other types of biomass as an energy source. International Energy Journal, 15(1).

Bianchi, F. D., Mantz, R. J., & De Battista, H. (2007). The wind and wind turbines (pp. 7-28). Springer London.

Blanco, M. I. (2009). The economics of wind energy. Renewable and sustainable energy reviews, 13(6), 1372-1382.

Blom, I. (2010). *Environmental impacts during the operational phase of residential buildings*, Vol. 37. IOS Press.

Bribián, I.Z., Capilla, A.V., Usón, A.A. (2011). Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. *Building and Environment*, *46* (5): 1133-1140.

Brookshier, P. (2004). Hydropower technology. Encyclopedia of energy, 3, 333-341.

Brophy, V., & Lewis, J. O. (2011). A green vitruvius: principles and practice of sustainable architectural design. Routledge.

Cleantechnica, (2017). Available at: https://cleantechnica.com/2017/03/16/eu-share-renewables-continues-near-2020-target/

Clip art solar power library, (2017). available at http://clipart-library.com/download-solar-panel-gif.html

CML (2017a). Cerca Fernandina. Available at http://www.cm-lisboa.pt/equipamentos/equipamento/info/cerca-fernandina (Jan., 2017)

CML (2017b). Freguesia de Sta. Maria Maior. Available at http://www.cm-lisboa.pt/municipio/juntas-de-freguesia/freguesia-de-santa-maria-maior (Jan., 2017)

Debatepedia, (2017). http://www.debatepedia.com/en/index.php/Debate:_Geothermal_energy

DGEG (2014). Available at http://www.dgeg.gov.pt/ (May, 2017)

DGEG/PORDATA (2017a). Available at https://www.pordata.pt/MicroPage.aspx?DatabaseName=Portugal&MicroName=Consumo+de+energia+prim%C3%A1ria+total+e+por+tipo+de+fonte+de+energia&MicroURL=1130& (May, 2017)

DGEG/PORDATA (2017b). Available at https://www.pordata.pt/DB/Portugal/Ambiente+de+Consulta/Tabela (May, 2017)

DGEG/PORDATA, (2017c) Available at https://www.pordata.pt/Portugal/Produção+de+energia+eléctrica+total+e+a+partir+de+fontes+renováveis-1127 (May, 2017)

Cleveland, C. J., Costanza, R., Hall, C. A., & Kaufmann, R. (1984). Energy and the US economy: a biophysical perspective. *Science*, *225*(4665), 890-897.

Ecofys, (2013). Available at: https://ec.europa.eu/energy/sites/ener/files/documents/nzeb_full_report.pdf .

EDF (w.d.). *Le guide des matériaux pour l'isolation thermique*. Available at http://doctechno.free.fr/IMG/pdf/EDF_Guide_isolation_thermique.pdf (May, 2017)

EU (2010). Available at http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=EN (May, 2017)

European Marine Energy Centre (2017). Available at http://www.emec.org.uk (May, 2017)

Feige, A., Wallbaum, H., Janser, M., & Windlinger, L. (2013). Impact of sustainable office buildings on occupant's comfort and productivity. Journal of Corporate Real Estate, 15(1), 7-34.

Flickr, (2017). Available at: https://www.flickr.com/photos/vitor107/3754554614

German Energy Agency. (2006). Green Building enhanced energy efficiency for non-residential buildings. *Deutsche Energie-Agentur GmbH (dena)*.

Givoni, B. (1992). Comfort, climate analysis and building design guidelines. *Energy and Buildings*, 18: 11-23

Givoni, B. (1998). *Climate Considerations in Building and Urban Design*. New York: Van Nostrand Reinhold

Global Peak Sun Hour, (2017). Available at: https://www.123zeroenergy.com/articles/187-how-many-solar-panels-do-i-need-to-power-my-house.html

Gonçalves, H., Graça, J.M. (2004). *Conceitos Bioclimáticos para os Edifícios em Portugal*. DGGE / IP-3E.

Greenandgrowing, (2017). https://www.greenandgrowing.org/biomass-advantages-disadvantages/

Green Building, (2006), Available at: www.eu-greenbuilding.org

Guardian, (2016). Available at: https://www.theguardian.com/environment/2016/may/18/portugal-runs-for-four-days-straight-on-renewable-energy-alone

Huovila, P. (2007). *Buildings and climate change: status, challenges, and opportunities*. UNEP/Earthprint.

Hurter, S., & Haenel, R. (Eds.). (2002). Atlas of geothermal resources in Europe.

JF Sta. Maria Maior (2017). Available at http://www.jf-santamariamaior.pt/historia-freguesia.php (Jan., 2017)

Johansson, T.B. (1993). *Renewable energy: sources for fuels and electricity*. Island press.

Johnson, G. L. (1985). *Wind energy systems* (pp. 147-149). Englewood Cliffs (NJ): Prentice-Hall.

Kacira, M., Simsek, M., Babur, Y., & Demirkol, S. (2004). Determining optimum tilt angles and orientations of photovoltaic panels in Sanliurfa, Turkey. Renewable energy, 29(8), 1265-1275.

Khan, N., Kalair, A., Abas, N., & Haider, A. (2017). Review of ocean tidal, wave and thermal energy technologies. Renewable and Sustainable Energy Reviews, 72, 590-604.

Kibert, C. (1994). Establishing Principles and Model for Sustainable Construction. *Proceedings of the First International Conference of CIB TG 16*, Tampa, EUA.

Kibert, C.J. (2016). *Sustainable construction: green building design and delivery*. John Wiley & Sons.

Kongtragool, B., & Wongwises, S. (2003). A review of solar-powered Stirling engines and low temperature differential Stirling engines. *Renewable and Sustainable energy reviews*, *7*(2), 131-154.

Lantz, E., Hand, M., & Wiser, R. (2012). Past and Future Cost of Wind Energy: Preprint (No. NREL/CP-6A20-54526). National Renewable Energy Laboratory (NREL), Golden, CO.

Locher, H., Scanlon, A. (2012). Sustainable Hydropower–Issues and Approaches. In *Hydropower-Practice and Application*. InTech.

López, I., Andreu, J., Ceballos, S., de Alegría, I. M., & Kortabarria, I. (2013). Review of wave energy technologies and the necessary power-equipment. Renewable and Sustainable Energy Reviews, 27, 413-434.

Lisbonlux , (2017). Available at: https://www.lisbonlux.com/lisbon/praca-martim-moniz.html.

Menezes, M. (2009). A praça do Martim Moniz: etnografando lógicas socioculturais de inscrição da praça no mapa social de Lisboa. *Horizontes Antropológicos*, 15(32): 301-328.

Mumovic, D., Santamouris, M. (Eds.). (2013). *A Handbook of Sustainable Building Design and Engineering: "An Integrated Approach to Energy, Health and Operational Performance"*. Routledge.

Neila González, F.J. (2004). *Arquitetura bioclimática en un entorno sostenible*. Arquitetura y Tecnologia, 4. Madrid: Editorial Munilla-Lería

Ocean Power Technologies (2017). Available at http://www.oceanpowertechnologies.com (May, 2017)

OECD (2003). Organization for Economic Co-operation and Development. *Environmentally Sustainable Buildings–Challenges and Policies*. OECD Observer, (July).

Okot, D. K. (2013). Review of small hydropower technology. Renewable and Sustainable Energy Reviews, 26, 515-520.

ONU (1992), Agenda 21, Rio Declaration. United Nations Conference on Environment and Development. Available at http://www.un-documents.net/agenda21.htm (Apr., 2017).

Patel, B. (2013). Project on Renewable Sources with focus on Solar Energy Industry of India.

Pelamis Wave Power (2017). Available at http://www.pelamiswave.com (May, 2017)

Pereira, P. (2015). A Produção Fotovoltaica em Portugal - Análise da legislação em vigor e do custo/benefício. Dissertação do Mestrado Integrado em Engenharia Eletrotécnica e de Computadores Major Energia. FEUP

Peuportier, B., Leurent, F., Roger-Estrade, J. (Eds.). (2016). *Eco-Design of Buildings and Infrastructure: The Textbook*.

Pfeffer, J. (2010). Building sustainable organizations: The human factor. The Academy of Management Perspectives, 24(1), 34-45.

Popescu, D., Bienert, S., Schützenhofer, C., & Boazu, R. (2012). Impact of energy efficiency measures on the economic value of buildings. Applied Energy, 89(1), 454-463.

Rogelj, J., Hare, W., Lowe, J., van Vuuren, D.P., Riahi, K., Matthews, B., Hanaoka, T., Jiang, K., Meinshausen, M. (2011). Emission pathways consistent with a 2 $^{o}$C global temperature limit. *Nature Climate Change*, 1(8), 413-418.

Roche, V., Sternai, P., Guillou-Frottier, L., Jolivet, L., & Gerya, T. (2017, April). Eastern Mediterranean geothermal resources and subduction dynamics. In *EGU General Assembly Conference Abstracts* (Vol. 19, p. 13427).

Schiavon, S.; Hoyt, T.; Piccioli, A. (2014). Web application for thermal comfort visualization and calculation according to ASHRAE Standard 55. Building Simulation, 7: 321–334

Shah, A., Torres, P., Tscharner, R., Wyrsch, N., & Keppner, H. (1999). Photovoltaic technology: the case for thin-film solar cells. science, 285(5428), 692-698.

Sharing Cities Programme (2016). Available at http://www.sharingcities.eu/ (May, 2017)

Shevkar, S.S., Otari, K.A. (2015). Tidal energy harvesting. *International Journal of Science, Engineering and Technology Research*, *4*(4), 990-994.

Smith, Z.A., Taylor, K.D. (2008). *Renewable and alternative energy resources: a reference handbook.* ABC-CLIO.

Solarelectricityhandbook, (2017). Available at: http://solarelectricityhandbook.com/solar-angle-calculator.html

Tester, J.W., Drake, E.M., Driscoll, M.J., Golay, M.W., Peters, W.A. (2012). *Sustainable energy: choosing among options*. MIT press.

Timeanddate, (2017). Available at: https://www.timeanddate.com/sun/portugal/lisbon

Reinsch, T., Dobson, P., Asanuma, H., Huenges, E., Poletto, F., & Sanjuan, B. (2017). Utilizing supercritical geothermal systems: a review of past ventures and ongoing research activities. *Geothermal Energy*, *5*(1), 16.

UNEP (2000). The Montreal Protocol. Available at http://ozone.unep.org/pdfs/Montreal-Protocol2000.pdf (May, 2017)

UNEP-IETC (2003). United Nations Environment Programme, International Environmental Technology Centre. *Energy and Cities. Sustainable Building and Construction*. 1st edition.

UNFCCC (1998). The Kyoto Protocol. Available at http://unfccc.int/resource/docs/convkp/kpeng.pdf (May, 2017)

United Nations (2011). United Nations Framework Convention on Climate Change. *Report of the Conference of the Parties on its Sixteenth Session, held in Cancun from 29 November to 10 December* 2010 (FCCC/CP/2010/7/Add.1). Available at http://unfcc.int/resource/docs/2010/cop16/eng/07a01.pdf (May, 2017)

Vörösmarty, C.J., Green, P., Salisbury, J., Lammers, R.B. (2000). Global water resources: vulnerability from climate change and population growth. *Science*, 289(5477), 284-288.

Weather-and-climate, (2017). Available at: https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,lisbon,Portugal

Wikipedia, (2017), available at: https://en.wikipedia.org/wiki/Permeable_paving

Windfinder, (2017). Available at: https://www.windfinder.com/windstatistics/lisboa.

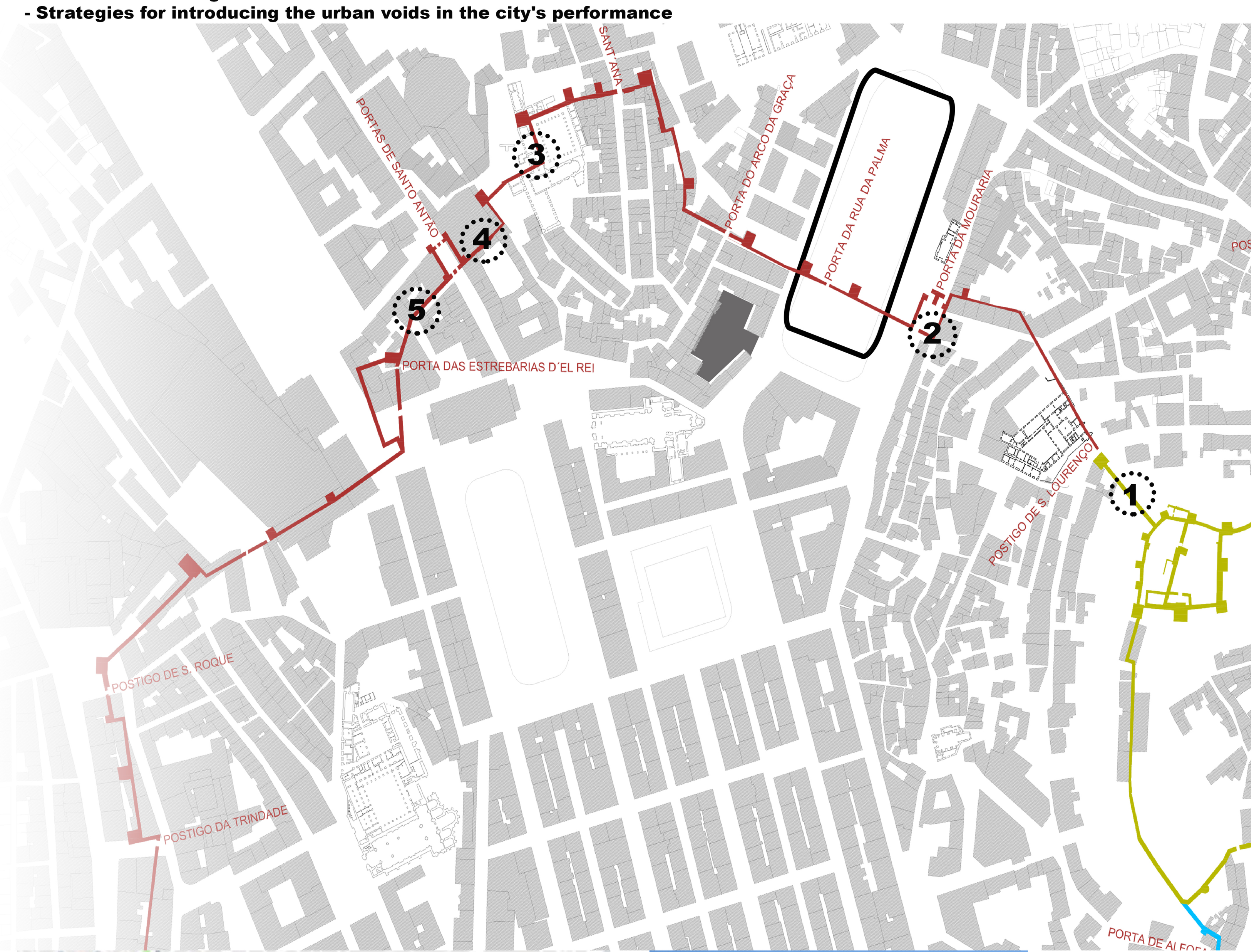
Zondag, H. A., Van Helden, W. G. J., Bakker, M., Affolter, P., Eisenmann, W., Fechner, H., ... & Tripanagnostopoulos, Y. (2006). PVT roadmap. A European guide for the development and market introduction of PVT technology.

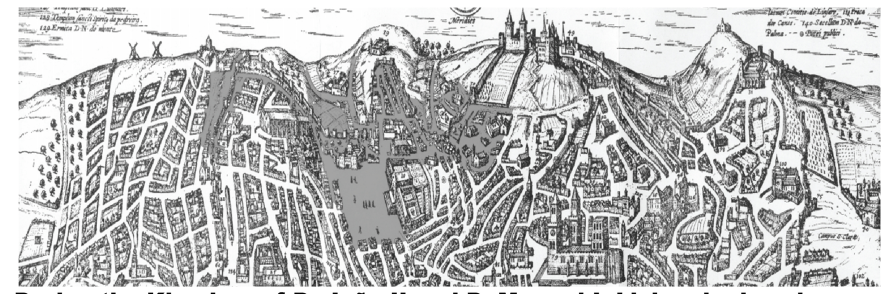
# 7 Appendixes:

# SUSTAINABLE BUILDINGS AND RENEWABLE ENERGY
# A CASE STUDY OF A PUBLIC LEISURE CENTER DESIGN

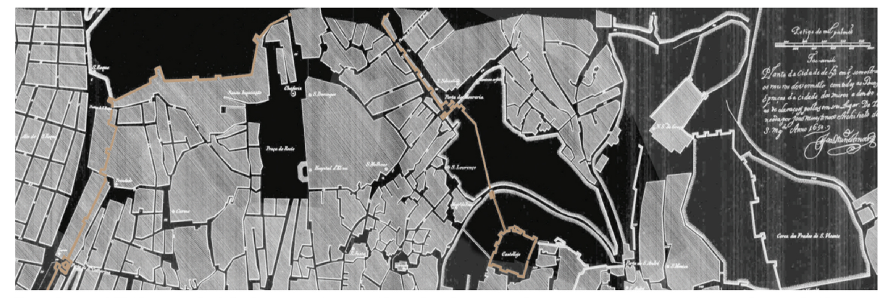
## Morphology

- Lisbon city started through Fernandina Fence (Cerca Fernandina)
- From São Jorge castle, passing by Martim Moniz, Jogo da Pela tower, continues from Santana gate to Santo Antão gate.
- One of the main historical symbol of Lisbon
- Poor accessability
- An Opportunity for a museological route to the concentrated touristic spots
- Obsolete spaces in this zone "What are these empty spaces in the city?"
- Absence of construction, absence of people, residual space, places that can be used to improve the economy of the city and open a new vision to the precious historical points
- Urban Void: lacking an evident function
- Strategies for introducing the urban voids in the city's performance

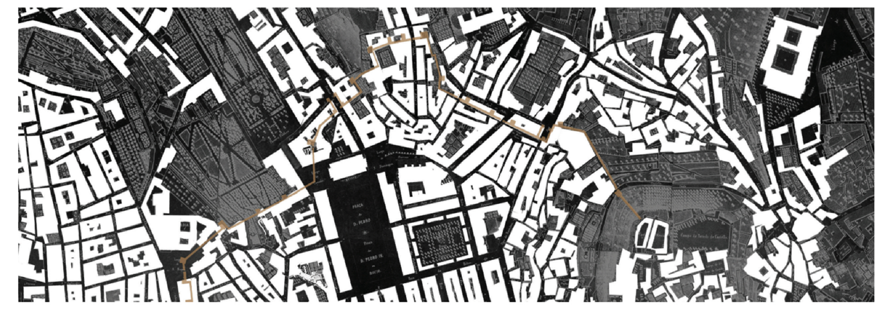


During the Kingdom of D. João II and D. Manuel I, Lisbon had such a great development that its constructions began to occupy spaces outside the walls built by D. Fernando (Cerca Nova or Cerca Fernandina).

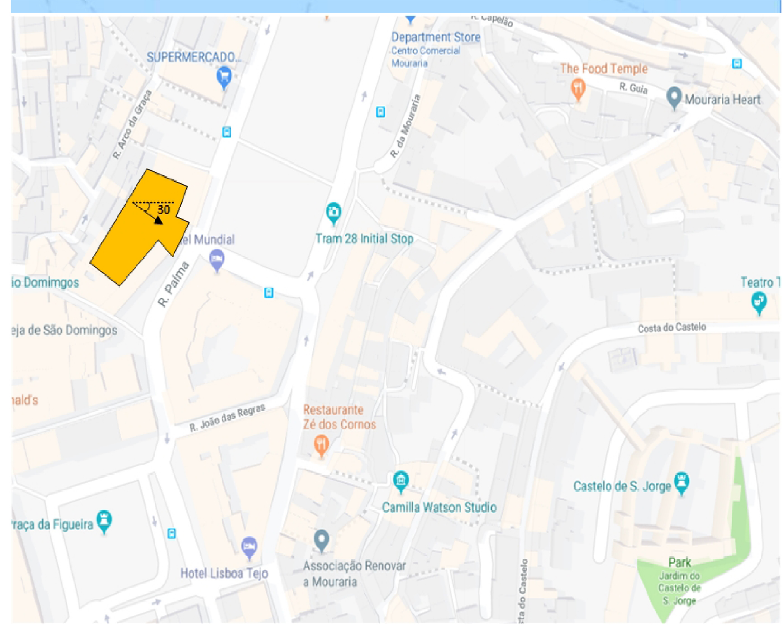


During 17th and 18th century the independence was restored and the country's largest colony, Brazil, transformed Lisbon into a wealthy city. Lisbon suffered a terrible earthquake that destroyed a large part of it. 1st Marquis of Pombal used the riches from Brazil to rebuild Lisbon Baixa with large Classical style avenues.



Avenida da Liberdade in the second half of the nineteenth century formed the backbone of a vast urban program outlined by Frederico Ressano Garcia.

The urban structure where currently fits the square, remained practically unchanged until the first half of the twentieth century.

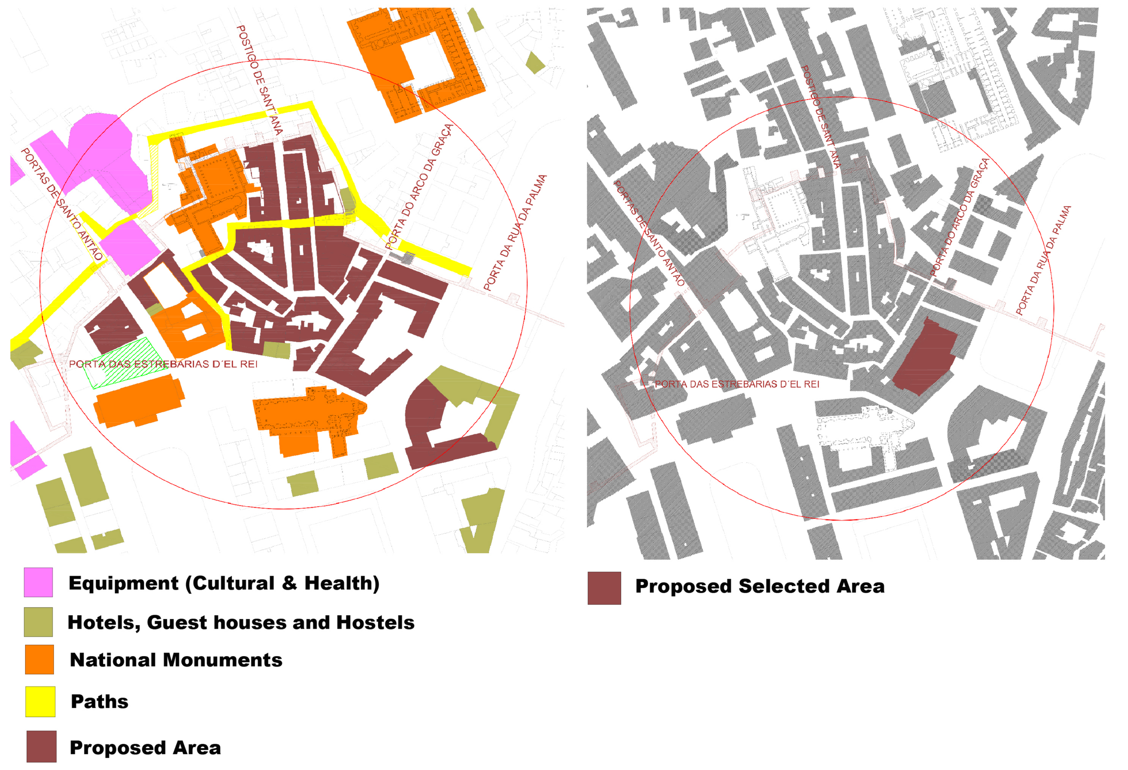
(1)

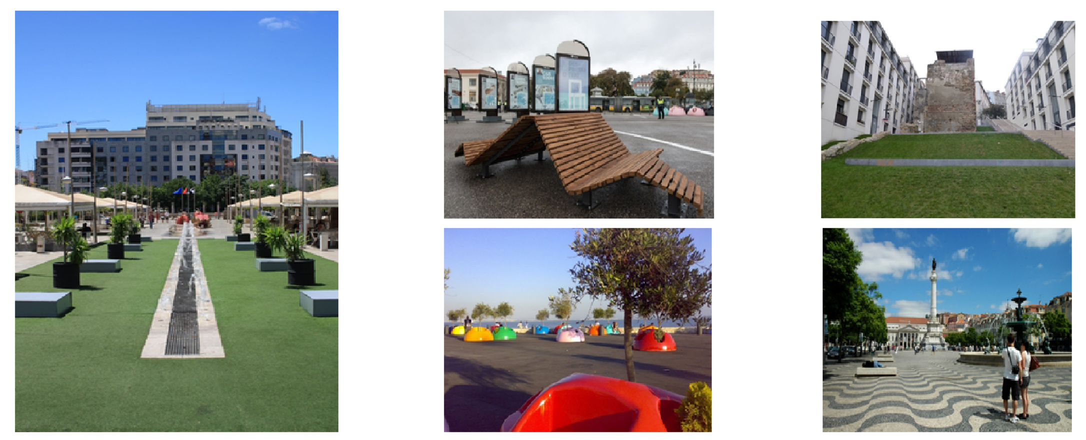
(2)

(3)

(4)

(5)

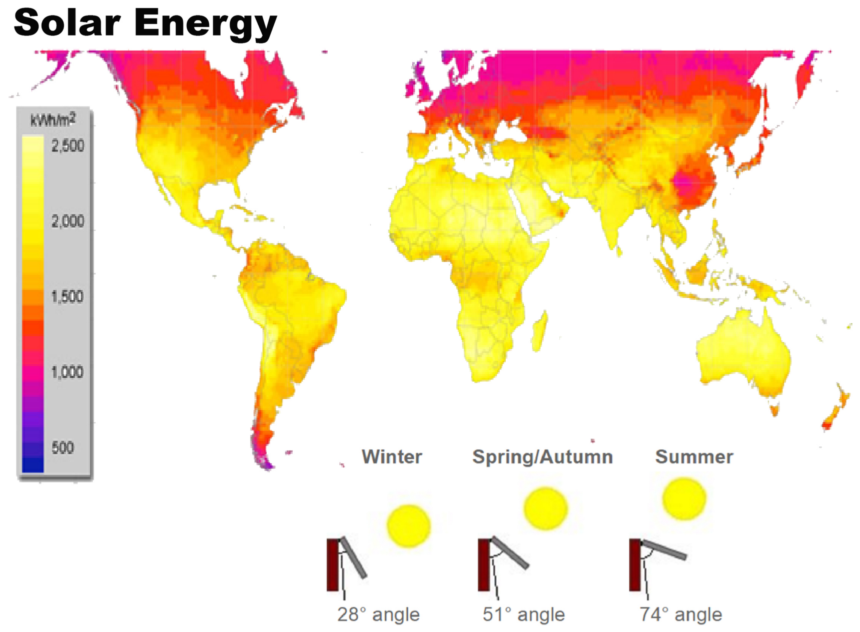



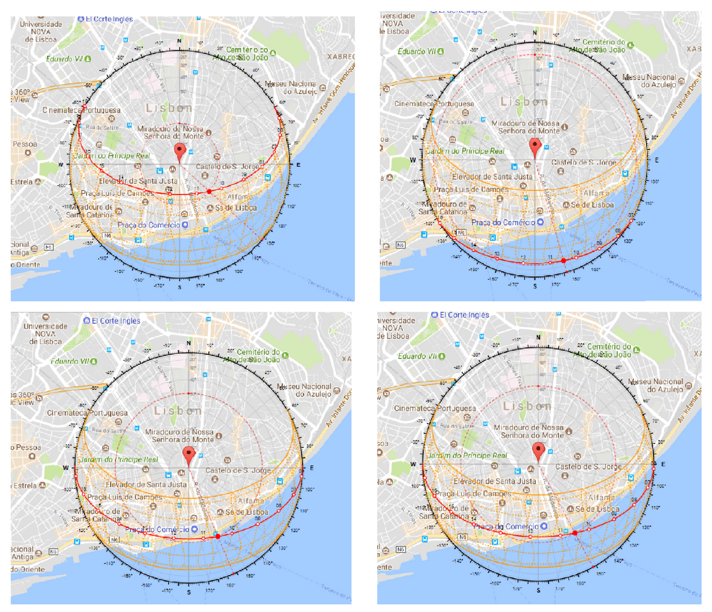



## Objetives

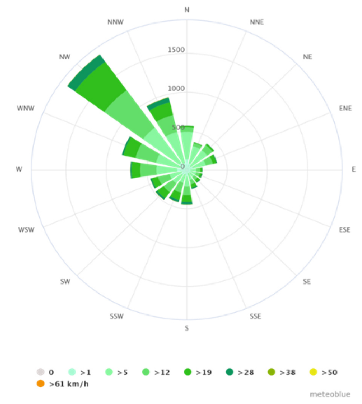
- The main goal of this project is to design a commercial sustainable building in an empty space in Martim Moniz in Lisbon that increases comfortability for the citizens.
- To study different renewable energy resources and utilization process.
- To inderstand the importance of sustainable buildings
- To study architectural elements of the structure which affect the energy usage of the building.
- To solve challenges in the historical part of Lisbon city for becoming green and sustainable.
- To assess the capability of empty spaces in the project site

### Solar Energy

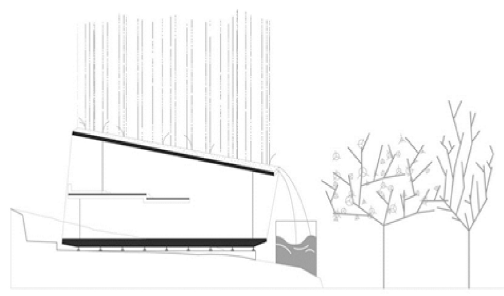


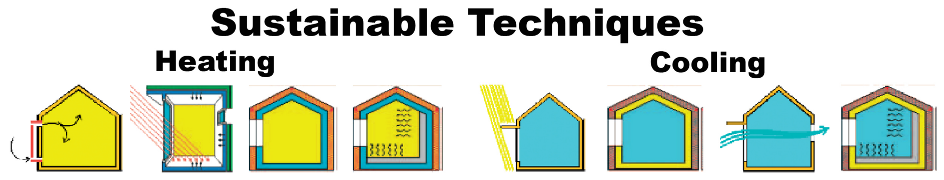
### Wind Direction



### Rain Water Harvesting

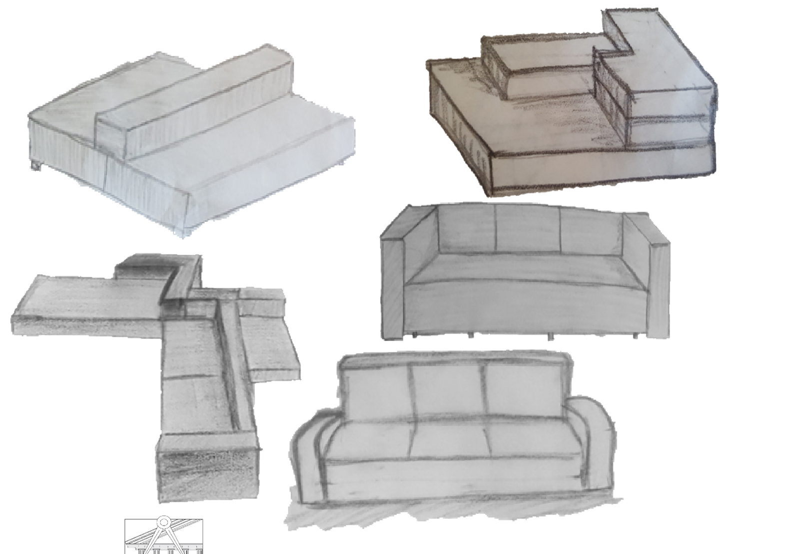


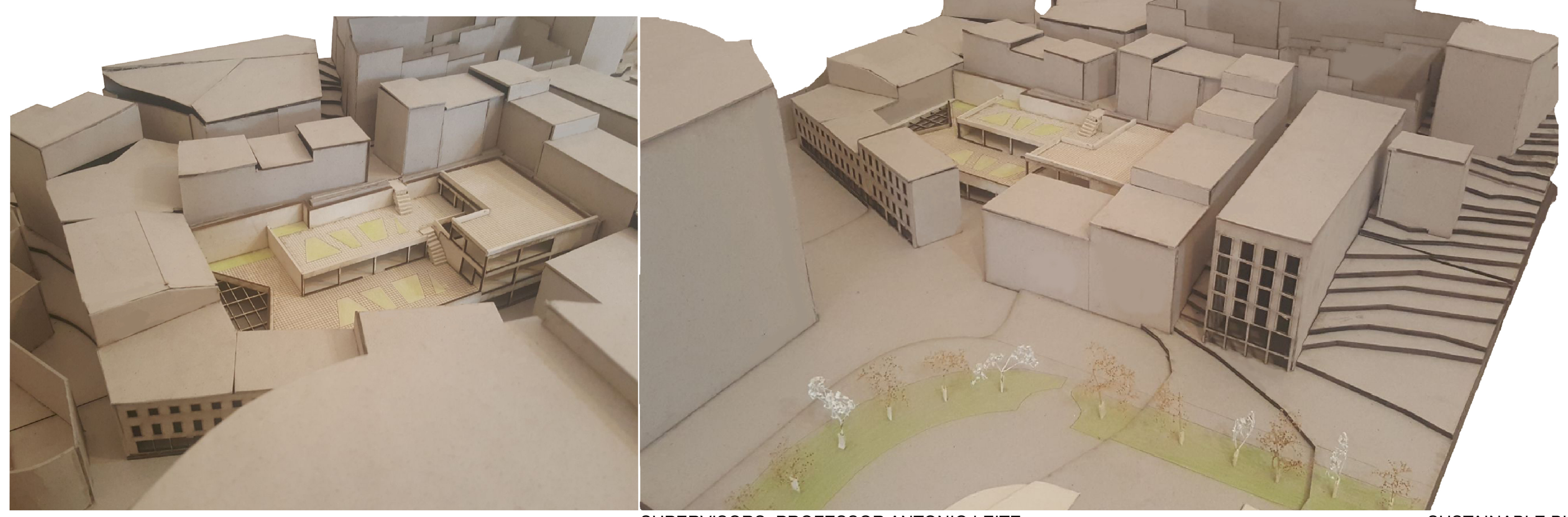
### Sustainable Techniques




## Concept Design

- A feasibility study in the region shows the need for a Health club, a sport shop, a restaurant with a view to Castle Jorge and one tourist information office. So, the building is a commercial building with leisure purposes.
- A sofa for citizens to enjoy the nice view of historical symbol of the city





## Characterization of the area

- Location: 38o42'54.93"N and 9o8'14.40"W
- High slope of the site
- The building designed is faced to Palma St. (at 12.5 m of height from sea level and contiguous to Martim Moniz Sq.), while its backed to Arco da Graça St. (at 24.5 m of height from sea level).
- The available area for construction is 2034 m2.
- Faced to the south east with 30 degrees of trim from west-east line.

## General data of the site

- Area: 1,49 km2
- Population (2011): 12,765
- Accommodation (2011): 10,729

- It represents 2% of the territory of the city but 5% of the buildings, which this indicator means it has twice the density of the city.

FACULDADE DE ARQUITECTURA DA UNIVERSIDADE DE LISBOA

FINAL MASTER PROJECT

SUPERVISORS: PROFESSOR ANTONIO LEITE
PROFESSOR JORGE RIBEIRO

SUSTAINABLE BUILDING AND RENEWABLE ENERGY –
A CASE STUDY OF A PUBLIC LEISURE CENTER DESIGN

MINA ABBASI TOUGHCHI

20101613

SCALE 1:500

SITE PLAN
LONGITUDINAL ELEVATION

P 02


Legend: 1_Engine Room 2_Equipment room for pool 3_Storage

FACULDADE DE ARQUITECTURA DA UNIVERSIDADE DE LISBOA | FINAL MASTER PROJECT | SUPERVISORS: PROFESSOR ANTONIO LEITE, PROFESSOR JORGE RIBEIRO | SUSTAINABLE BUILDING AND RENEWABLE ENERGY – A CASE STUDY OF A PUBLIC LEISURE CENTER DESIGN | MINA ABBASI TOUGHCHI | 20101613 | SCALE 1:200 | FLOOR –1 PLAN _ SECTION CD

P 03


Legend: 4_Lobby 5_Secretary 6_Bar 7_Kitchen 8_Cold storage 9_Dry storage 10_Bathroom for staff 11_Reception 12_Pilatis room 13_Equipment room 14_Patio 15_Bathroom and changing room for clients(females and males) 16_Spa rooms 17_Bathroom and staffs changing room 18_Dry sauna 19_Wet sauna 20_Infant pool 21_Swimming pool 22_Jacuzzi



Legend: 23_Bathroom and changing room for clients 24_Physicion room 25_Equipment room 26_Gym room 27_Balcony 28_Storage 29_Tourist information center 30_Bathroom and changing room for staff 31_Sport shop 32_Green space

FACULDADE DE ARQUITECTURA DA UNIVERSIDADE DE LISBOA

FINAL MASTER PROJECT

SUPERVISORS: PROFESSOR ANTONIO LEITE
PROFESSOR JORGE RIBEIRO

SUSTAINABLE BUILDING AND RENEWABLE ENERGY – A CASE STUDY OF A PUBLIC LEISURE CENTER DESIGN

MINA ABBASI TOUGHCHI

20101613

SCALE 1:200

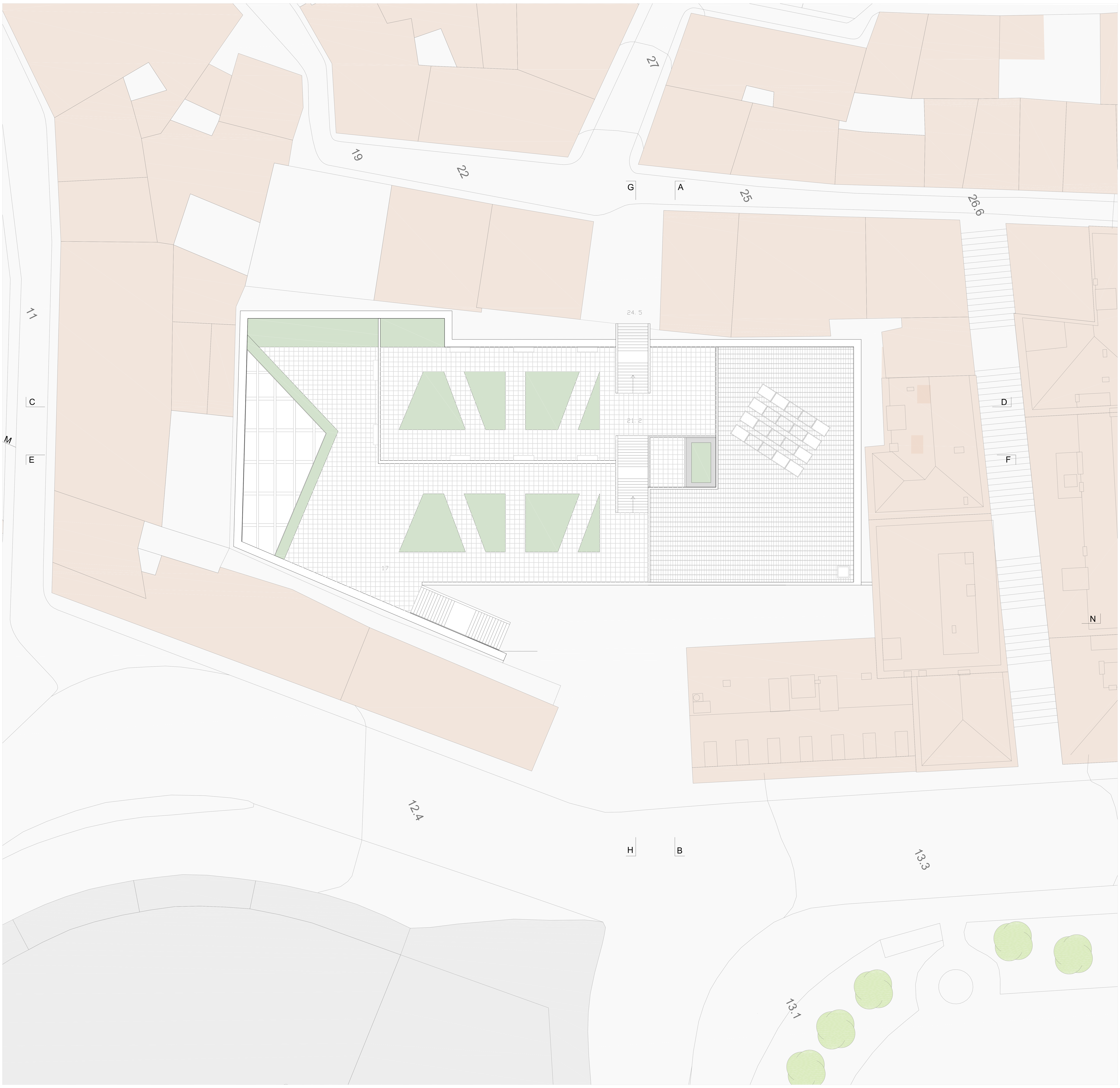
SECOND FLOOR _ SECTION AB

P 05



Legend: 33_Entrance for stuff 34_Reception 35_Bathroom and changing room for stuff (M/W) 36_Dry storage 37_Cold storage 38_Restaurant 39_Kitchen 40_Main saloon 41_Bathroom for clients (W/M)

FACULDADE DE ARQUITECTURA DA UNIVERSIDADE DE LISBOA | FINAL MASTER PROJECT | SUPERVISORS: PROFESSOR ANTONIO LEITE, PROFESSOR JORGE RIBEIRO | SUSTAINABLE BUILDING AND RENEWABLE ENERGY – A CASE STUDY OF A PUBLIC LEISURE CENTER DESIGN | MINA ABBASI TOUGHCHI | 20101613 | SCALE 1:200 | THIRD FLOOR _ SECTION GH




FACULDADE DE ARQUITECTURA DA UNIVERSIDADE DE LISBOA
SUPERVISORS: PROFESSOR ANTONIO LEITE
PROFESSOR JORGE RIBEIRO

FINAL MASTER PROJECT

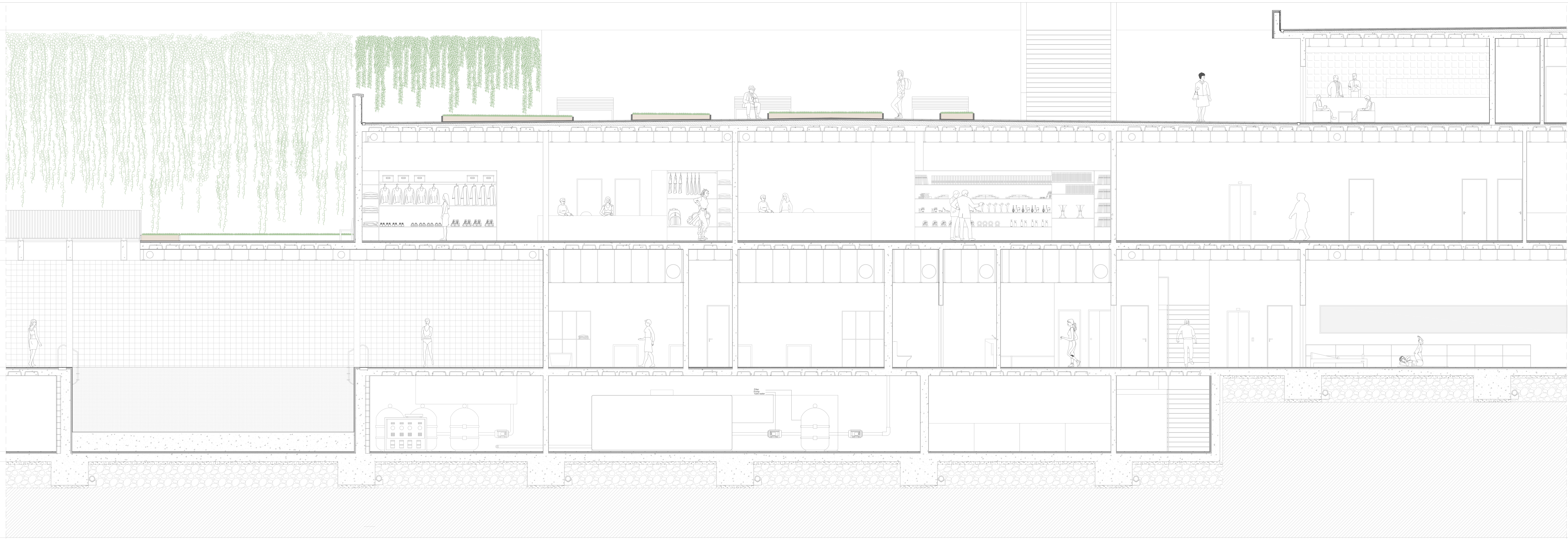
SUSTAINABLE BUILDING AND RENEWABLE ENERGY –
A CASE STUDY OF A PUBLIC LEISURE CENTER DESIGN

MINA ABBASI TOUGHCHI
20101613

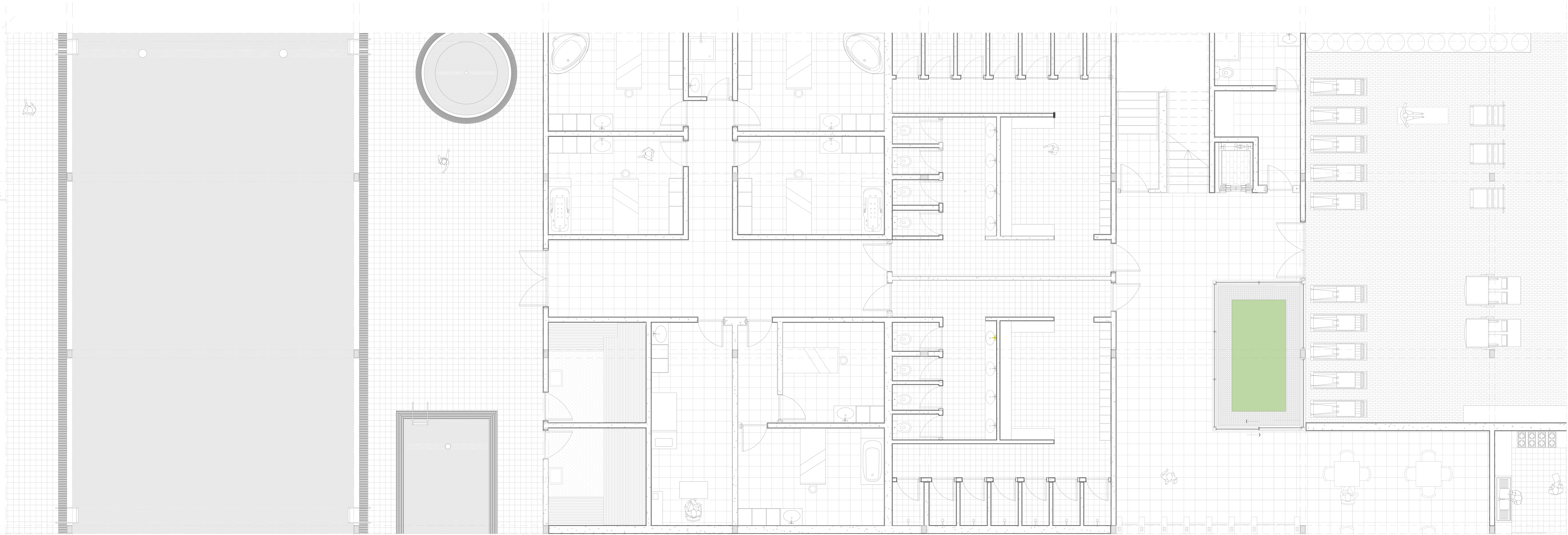
TOPPING PLAN
ELEVATION PLAN MN

SCALE 1:200

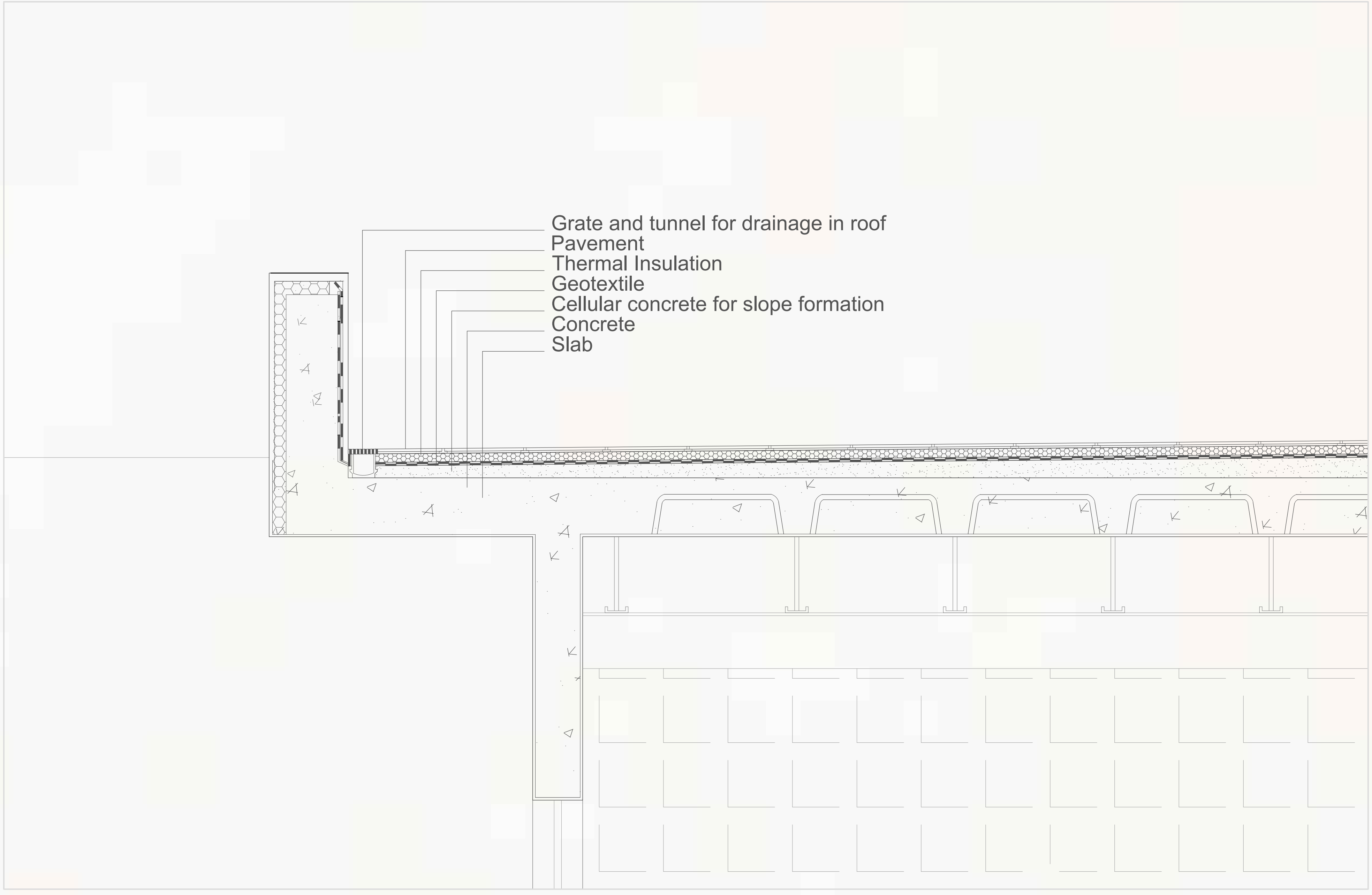
P 07



C

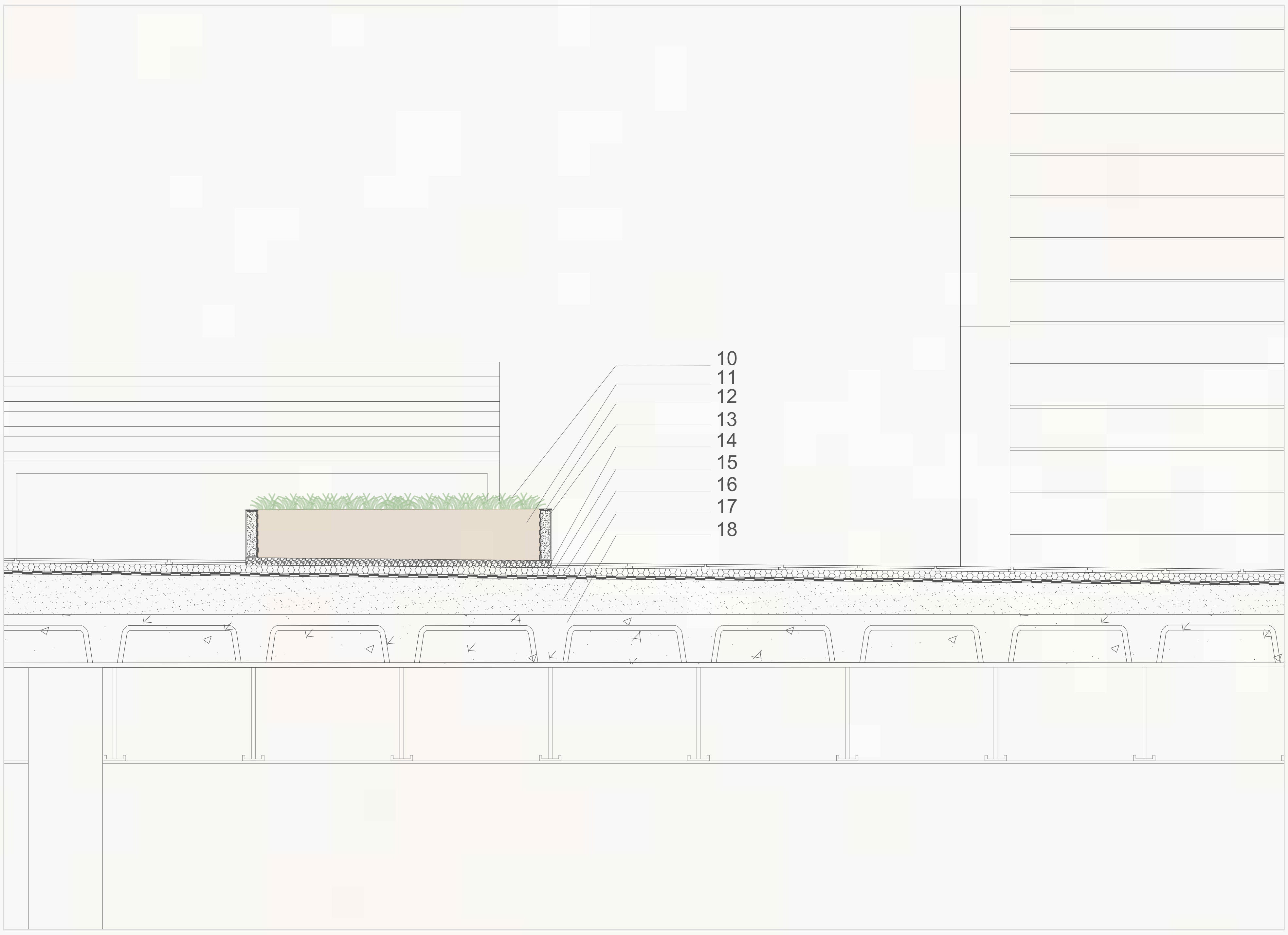


D

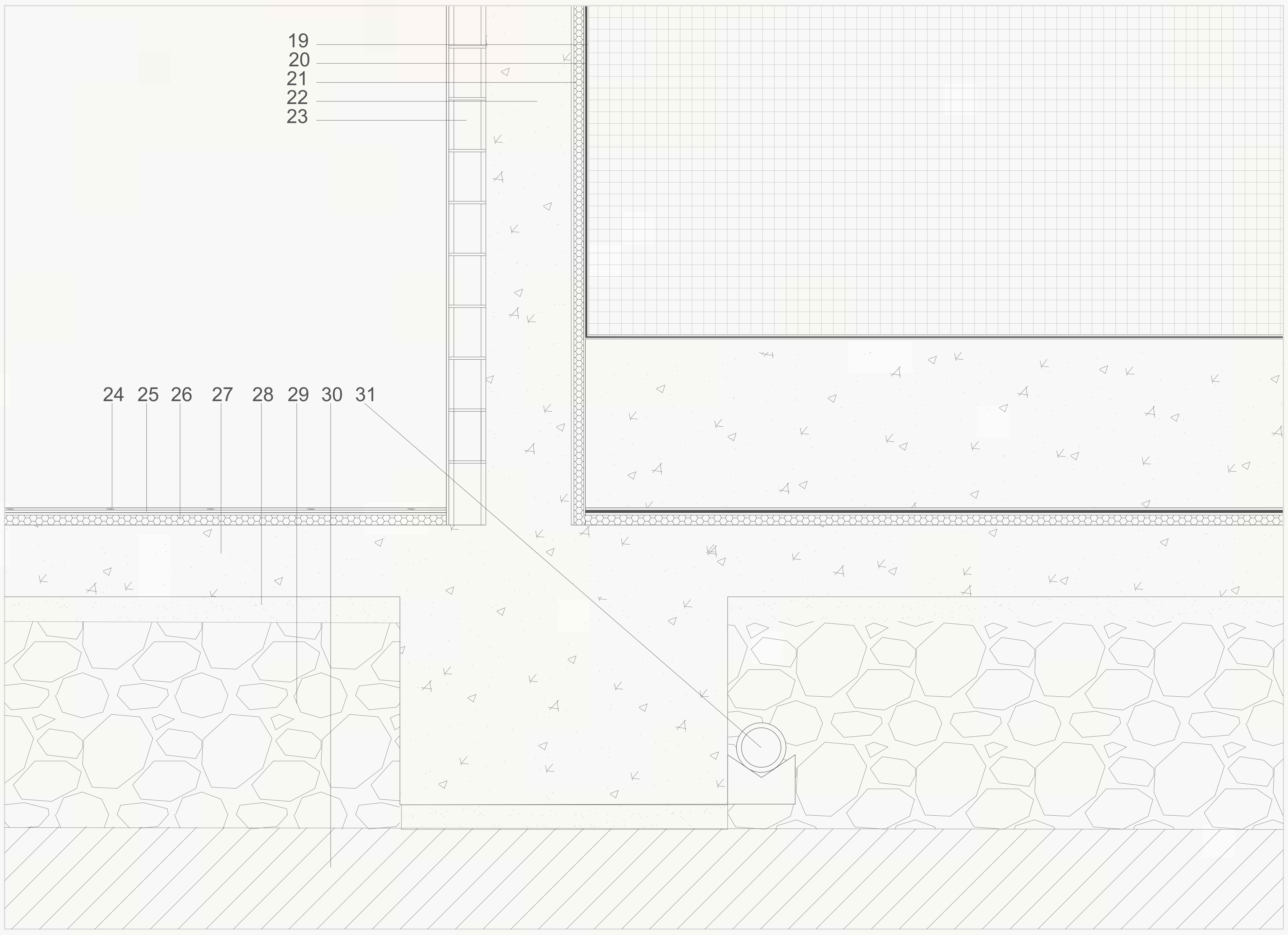



## LEGEND :

1_Grate and tunnel for drainage in roof
2_Pavement
3_Thermal Insulation
4_Geotextile
5_Cellular concrete for slope formation
6_Concrete
7_Slab
8_Hanger in false ceiling




10_Grass
11_Soil
12_Geotextile
13_Concrete
14_Drainage layer
15_Thermal Insulation
16_Geotextile
17_Cellular concrete for slope formation
18_Concrete




19_Ceramic finishing
20_Mortar regularization
21_Thermal isulation
22_Reinforced concrete
23_Concrete block
24_Pavment of floor(cement)
25_Leveling Mortar
26_Thermal Insulation
27_Concrete
28_Cleaning Concrete
29_Hardcore
30_Ground
31_Drain Colector